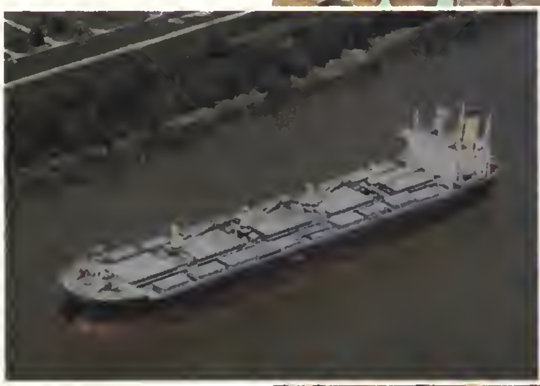
Costs and Benefits of Redefining the Grade Factor

Broken Corn and Foreign Material






Lowell D. Hill
Charles R. Hurburgh, Jr.
Karen L. Bender
Bruce L. Meinders

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Lowell D. Hill and Karen L. Bender

Lowell D. Hill is the L.J. Norton Professor of Agricultural Marketing in the Department of Agricultural Economics at the University of Illinois at Urbana-Champaign. ■ Karen L. Bender is a Senior Research Specialist in the Department of Agricultural Economics at the University of Illinois at Urbana-Champaign.

Charles R. Hurburgh, Jr. and Bruce L. Meinders

Charles R. Hurburgh, Jr., is a Professor in the Agricultural and Biosystems Engineering Department at Iowa State University. ■ Bruce L. Meinders was a Pre-doctoral Research Associate in the Agricultural and Biosystems Engineering Department at Iowa State University.

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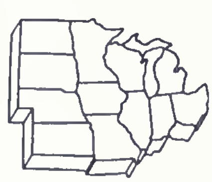

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Abstract

The grade factor of Broken Corn and Foreign Material (BCFM) is the most frequent cause of lowering the grade of corn in the market channel. Because the definition of this grade factor includes broken kernels and corn dust as well as non-corn material, it has been frequently proposed that the factor be separated into two factors—Broken Corn (BC) and Foreign Material (FM). Samples obtained at each point in the market channel identified that most of the material classified as BCFM or corn screenings (material removed from the corn by mechanical devices) was broken corn. Less than 0.5 percent of the weight of screenings was identifiable as non-corn material.

The results of this study show that separation on the basis of particle size would have little effect on the quality of corn in the market channel or on the value of the information provided by grades. If the two grade factors were accompanied by lower limits on their sum, the amount of BCFM at each point in the market channel could be decreased, but only at a significant cost of cleaning. Because additional broken kernels are created with each handling in the market channel, a significant reduction in BCFM could be achieved only by repeated cleaning. Even with this reduction in BCFM, the levels of BC at destination would still be above those on the origin certificate as the result of impacts due to handling between the export elevator and the importer's plant.

Significant reduction of BC at destination can only be accomplished by introducing incentives for delivering corn with greater resistance to breakage. Drying temperatures, genetic differences, harvest moisture, and combine adjustment all have an effect on breakage susceptibility. An alternative to separation on the basis of particle size is to separate the BCFM fraction into Coarse Foreign Material (CFM) and Total Broken Kernels (TBC). CFM would be defined as non-corn material readily removed by mechanical scalping. TBC would be all material passing through a 12/64-inch round-hole sieve. If accompanied by appropriate price differentials, this change in grades would encourage removal of CFM at the farm, and there would be little opportunity for reintroduction. TBC would be identified at each point in the market channel, allowing the buyer and seller to negotiate a price differential that would be appropriate for the intended use.

Executive Summary

The United States has a long history of research on the grade factor Broken Corn and Foreign Material, with many proposals submitted for changing the definition, sieve size, and grade limits. Broken Corn and Foreign Material were defined as two factors in 1914, combined into Cracked Corn and Foreign Material (CCFM) in 1916, and then named Broken Corn and Foreign Material (BCFM) in 1959. The idea of separating the factors was discussed in congressional hearings in 1937, 1976, and 1986. Sieve sizes were changed in 1915, 1916, and 1921. Proposals for changing sieve sizes were researched and debated in 1930, 1937, 1976, and 1986.

Importers of U.S. corn have registered their complaints about poor quality since the beginning of export trade from the United States. Most of these complaints have been related to the high levels of BCFM received after the corn was unloaded at the foreign destination. Numerous studies conducted intermittently over the past century have documented that levels of BCFM can increase dramatically between the level documented on the export certificate and that recorded at the processing plant at foreign destinations, especially when the corn has been handled several times and a vessel has been subdivided into numerous lots before the processor receives it. High levels of fine materials, dust, and broken kernels clearly reduce the value of the corn for all purposes.

One of the concerns of foreign buyers has been the lack of differentiation between non-corn material and the broken kernels and corn dust that are classified as BCFM by official grade standards. The value of broken corn is much greater than that of weed seeds or inert material, but the percent BCFM reported on the export certificate provides no information about the composition of BCFM in the corn. This lack of information also affects the value of corn screenings that are removed during cleaning to reduce the level of BCFM. Although the screenings generated by cleaning consist primarily of broken corn, the percent of weed seeds, chaff, and plant parts can vary widely.

Objectives of the Study

The objective of the current study was to evaluate the economic impact of separating the grade factor BCFM into two factors, with and without a reduction in the factor limits.

Although the original request for an economic impact study (initiated at the Grain Quality Workshops, sponsored by the National Grain and Feed Association) focused on the separation of BCFM into two factors, the potential for reducing the levels of BC and FM in the market channel was also included in the project objectives.

The issue of including a measurement of breakage susceptibility in grades was not specified in the original charge to the research team, but it became a question of importance as the study developed.

Assumptions and Procedures

Separation of BC and FM can take many alternative forms, with different definitions and factor limits. One or both of the factors could be made grade-determining. If one or both factors are grade-determining, there are several different possible limits for each numerical grade. Seven alternative scenarios, with as many as three variations each, were developed and evaluated on the basis of potential impacts.

The assumptions common to all scenarios were these: (1) changes in grades, such as factor definitions, do not change quality directly, and changes in quality come from actions by firms in response to economic incentives associated with grades; (2) changes in grades will not automatically shift profits from one sector of the industry to another; (3) improved quality will have little effect on total demand for corn, unless it results in substitution of corn for wheat or sorghum; (4) changes in grades will not significantly alter U.S. market shares in the world corn market; (5) in the aggregate, the price of corn reflects the value of the products derived from it minus costs of transportation and marketing; (6) the majority of U.S. corn exports will continue to be grade No. 3; and (7) grain producers and grain elevator managers will respond to changes in grades when opportunities exist for increasing value or decreasing costs. It was also assumed that the majority of corn in the market channel will be graded at each point and that defects that exceed the factor limits will be assessed an implicit or explicit discount.

A firm level budgeting model was developed to estimate costs and benefits to an individual firm from cleaning under several different economic conditions. The estimates required several assumptions about the level of BCFM in the corn at the farm and elevator, value of screenings, weather conditions, and prices of energy, corn, and screenings. Quantitative estimates of aggregate costs and benefits would require many additional assumptions about responses by managers and the operating conditions in each firm. Average values of the many influencing variables at the industry level were not available. This study used a qualitative approach for estimating aggregate impacts to avoid the implication that numerical values for the industry had been accurately calculated. Surveys of farmers, elevators, and buyers of screenings provided data on production, cleaning, and marketing practices and on attitudes of managers toward changing the BCFM grade factor.

Cleaning by Farmers and Elevator Managers

Current production, harvesting, and handling practices at farms and elevators result in levels of BCFM that often may exceed the limits of the No. 2 grade. To avoid price discounts, farmers or elevator managers must clean or blend to the allowable limit. Subsequent handling increases the percent of broken kernels, and additional cleaning may be required at the next point in the market channel. The level of BCFM in the corn delivered to the country elevator is usually less than the limit for No. 2 (3.0 percent). Interior elevators reported that less than 10 percent of their receipts from farmers graded below No. 2. Within the market channel the level of BCFM approached the limit for No. 2 corn because of increased breakage during handling and drying. BCFM in the export elevator often exceeded 4 percent, but most export corn at the time of loading was close to 4 percent BCFM — the grade limit for No. 3 corn. Excess screenings were removed at each point in the market channel. BCFM increased approximately 0.5 percent during each elevation and transfer in interior elevators. The increase was greater during loading and unloading of the ocean vessel. The volume of corn screenings in the market channel was estimated to be over 2 million tons (70 million bushels), which is approximately 1 percent of the total volume of corn handled by grain marketing firms.

The average volume of screenings removed by farmers with cleaners was 23.6 tons per farm in 1990. Animal feed was the primary market for both farm screenings and country elevator screenings. The majority of screenings not fed or sold to feeders were sold to brokers, for resale to feeders.

In a three-state survey (Iowa, Illinois, and Indiana), about 40 percent of the farmers reported using grain cleaners. Farmers with cleaners indicated the most important reason for cleaning corn was to increase storability. Other reasons given were to improve the grade or to avoid discounts and to increase the efficiency of drying and aerating. Incentives for cleaning included fewer discounts for excess BCFM, income from the sales of screenings removed, reduced physical shrink by having cleaner grain in storage bins, reduced damage from insects and mold, and reduced aeration costs.

The reported cost of operating a grain cleaner on the farm differed dramatically from farm to farm but averaged 2.7 cents per bushel for removing an average of 2 percentage points of BCFM. Respondents did not identify fixed and variable costs separately but made a gross estimate of costs per bushel. The average fixed-plus-variable cost estimated in an economic engineering model of machine operation was 1.0 to 1.5 cents per bushel. Other costs associated with cleaning include the loss of weight in

BCFM removed that could have been sold at the price of corn, additional costs of storing or disposing of the screenings, and the cost of transportation if the screenings are sold to a buyer located off the farm.

Country elevators marketed over 1.5 million tons of screenings in 1989. The majority of screenings were sold to farmers or feeders, sold to brokers, or used in their own feed mill.

Based on the survey of interior elevators, 64.2 percent of interior elevators have cleaners installed, and 78.6 percent of those with cleaners used them in 1988 or 1989. Most elevators had gravity cleaners with square mesh screens, and elevators removing the most screenings operated their cleaners at higher throughput. On average, these elevators cleaned about one-half of their receipts and shipments, removing 2.15 percentage points of BCFM from the corn they cleaned. The use of cleaners differed by type of firm, with river elevators using cleaners less frequently than country and sub-terminal elevators.

The destination of corn shipped from the country elevator influenced the amount of cleaning. Elevators whose primary market was a processor or an exporter reported more frequent cleaning than those shipping to farmers or river elevators. Elevator size (as measured by storage capacity or annual volume) was not related to percentage points of BCFM removed during cleaning, although the quantity of screenings sold increased by 0.25 ton for each 1,000-bushel increase in receipts from farmers.

Properties of Corn Screenings

Almost any cleaning operation results in corn screenings, with particle sizes ranging from whole kernels to dust. Most of the material smaller than whole kernels is broken corn. Non-corn materials such as weed seeds may be found in any particle size but tend to be concentrated in particle sizes below 4.0 mm (10/64 inch). The proportions of the various particle sizes of corn remain relatively constant as corn moves through the market channel, even though the proportion of broken corn relative to non-corn material in BCFM and corn screenings increases due to the increase in broken corn. The relative amounts of BC and FM in corn samples from country elevators, barges, and export elevators were approximately the same; FM was 21 percent of BCFM.

BCFM is determined by a 12/64-inch sieve in the Carter-Day Dockage Tester, whose results are correlated with, but not identical to, those of a commercial cleaner. Commercial cleaners remove a relatively higher proportion of the smaller particles than the Carter-Day Dockage Tester. Samples of commercial corn screenings obtained from country elevators contained a higher proportion of the smaller particle sizes than would have been predicted from laboratory (Carter-Day Dockage Tester) cleaning of corn samples.

Samples of commercial corn screenings obtained from country elevators contained an average of 55.8 percent BC (between the 12/64-inch and 6/64-inch sieves), 26.7 percent FM (6/64-inch and below), and 17.5 percent "corn" (greater than 12/64-inch diameter). The larger particles of broken corn that are included in commercial screenings represent an economic loss to the elevator. Based on survey results, this loss was estimated to be about 0.3 cent per bushel when corn price is $2.75 per bushel and screenings are selling at a 25 percent discount to corn.

A statistically derived equation was successful in estimating the relative concentrations of BC and FM in corn. The percent BCFM was a good predictor of the percent FM. The particle-size distribution within samples of corn was not correlated with any other official grade factor, and no causality could be identified between the level of BCFM in the sample, the ratio of BC to FM, and the values for the grade factors of test weight and damage.

As cleaners were operated closer to rated capacity, the relative amount of FM in the screenings decreased and the relative amount of corn increased, resulting in an economic loss. Additional cleaning would probably result in still more corn in screenings, further increasing economic losses. Capacity, design, and operating characteristics of commercial cleaners did not affect chemical composition, aflatoxin, or fumonisin levels in the screenings.

Although cleaning strategies had a significant effect on particle size distribution in screenings, cleaning strategy did not affect the distribution of particle sizes in the cleaned corn. Different flow rates, different models, and different screen sizes had little effect on the ratio of BC to FM in the cleaned corn. Total BC plus FM in cleaned corn could be lowered by changing cleaning strategies, but the ratio remained similar to the current ratio.

Corn screenings, whether from the Carter-Day Dockage Tester separation or from commercial cleaners, contained less starch and more fiber than whole corn. The fiber content was more variable among samples than the other constituents. Protein content increased as particle size decreased, so screenings contained more protein than corn. However, the energy content of screenings declined as particle size decreased. The feeding value of corn screenings is thus dependent on relative prices of energy and protein. The loss of value is less than the typical market discount for screenings relative to corn (i.e., the discounts for BCFM relative to corn are greater than the differences in feed value).

In corn screenings, protein and oil contents were positively correlated, and protein and starch contents were negatively correlated. Smaller particle sizes had lower bulk densities (test weights) but higher particle densities than larger particle sizes. Material up to at least 12/64-inch diameter must be included with screenings for them to weigh about 40 pounds per bushel (a common base quality for pricing screenings). Fines (through the 6/64-inch sieve on the Carter-Day Dockage Tester) had an average test weight of 33.5 lb/bu. The space required to store a ton of screenings is higher than for corn as a result of the lower test weight.

The price of screenings is fairly responsive to changes in the quantity of screenings in the market channel, with an estimated reduction in price of 14 cents per ton associated with an increase of 1,000 tons of screenings.

Users of screenings identified moisture and test weight as the two most important characteristics in determining price and value. Particle size and chemical analysis were seldom identified as important factors, and only 22.2 percent of the respondents identified protein content as important in determining price or influencing purchasing decisions. The estimated composition and value of screenings currently are based primarily on test weight. Buyers of screenings estimated that a smaller screen size for defining screenings would reduce the value of screenings.

The possibility of the presence of toxins in corn screenings is a concern for livestock feeders. The samples of screenings from country elevators were analyzed for aflatoxin and fumonisin. Only one sample out of 62 contained measurable aflatoxin. Particle size did not significantly affect the level or incidence of aflatoxin in these samples or in previous studies. Separation of smaller particles will not create higher concentrations of aflatoxin in the fines, although the presence of fines in storage may accelerate biological activity that may result in aflatoxin development. Nearly all screenings samples contained fumonisin, with the smaller particle sizes having higher concentrations. The weighted average fumonisin content was 30 parts per million (ppm). In any particle size, high test weight was negatively correlated with fumonisin (less risk) and positively correlated with higher starch content.

Coarse FM (non-grain material readily removed by mechanical sieving) differs dramatically in chemical composition and physical properties from broken corn or whole kernels. CFM can have 10 to 12 times more fiber than broken corn, and its value for any use is quite low. The level of CFM at any point in the market channel is generally less than 0.2 percent. However, when expanded to the total export volume this represents a significant cost of transport and disposal at destination. The effect of CFM on perceived quality is much greater than the actual reduction in value.

Cost of Cleaning

The initial cost of the cleaner relative to the bushels cleaned has the greatest effect on cost of operating the cleaner. Economies of scale are substantial, and the cost per bushel declines rapidly as the number of bushels through the cleaner increases. Costs are also influenced by the efficiency of the cleaner. Cumulative and incremental cleaning efficiency multipliers can be used to estimate cleaning efficiency for any particle size or group of sizes, if the cleaning efficiency for BCFM (12/64-inch and below) is known.

The cost of operating a cleaner at the elevator was less than at the farm, primarily because of economies of scale. Thus a greater incentive would be required to induce farmers to purchase cleaners than to induce country elevator managers to increase the volume of corn cleaned. The benefits from cleaning for an individual firm are more difficult to quantify than the costs. Small amounts of fines can cause dramatic increases in airflow resistance. For example, the airflow resistance of corn with 3 percent BCFM is approximately twice that of clean corn. Removal of fines before storage may be justified on the basis of improved storability, lower energy required for aeration, and more profitable marketing opportunities, regardless of discounts and factor definitions. If corn contains at least 3 percent BCFM and will be stored 3 months or more, net benefits of 1 to 3 cents per bushel are theoretically possible from cleaning. Considerable operator skill is required to capture these benefits.

Creating an incentive for increased cleaning requires a significant reduction in limits on BCFM. The magnitude of the incentive for cleaning at the farm and the elevator depends upon the market response to the lower limit on BCFM. Prices and discounts control the economic gain or loss from additional cleaning. If FM is set at zero and charges are assessed for cleaning in addition to the weight subtraction, incentives may exceed costs. However, if a FM allowance of even 0.2 or 0.3 percent is given by the buyer and the only disincentive is a weight subtraction, additional cleaning capacity will probably not be purchased and the grade change will generate little change in quality.

Evaluating the Scenarios

Most scenarios evaluated in this study increased inspection costs and generated more discounts for producers. Among the seven scenarios and five variations evaluated using data from this study, only three (4b, 6c, and 7) have the potential for significantly improving corn quality in the export market. Of these, 4b could improve quality but only at a high cost of cleaning, segregating, and inspecting in the market channel. Scenarios 6c and 7 could improve quality by reducing CFM and would not require additional segregation. Additional costs would be much less than for Scenario 4b. The increased information and quality incentives of Scenario 6c would lower BCFM levels in the market channel by one percentage point, but the impact on destination quality would still be small, since susceptibility to breakage would not be changed. Inspection costs would be increased primarily because more time would be required to determine CFM.

Only Scenario 7, which includes a measure of breakage susceptibility, holds the promise of significant improvement in visual and intrinsic quality and a reduction in BCFM created during loading and unloading at the foreign destination.

Support for Separating the BCFM Factor

Implementing a proposal for changes in factor limits requires support from all segments of the industry. Active opposition with legitimate justification can override an economic evaluation. Surveys provided data on the support for change by market participants.

About 30 percent of farmers in the three-state survey favored changing or removing the BCFM factor in corn. Farmers reported that they believe that the most effective strategy for reducing BCFM levels is to offer more premiums for cleaner grain. Farmers also reported that cleaner grain could be achieved by improving harvesting practices, combine adjustments, and additional cleaning on-farm and at elevators.

When asked to identify strategies to reduce the amount of foreign material in corn, 30 to 34 percent of the farmer respondents in Iowa, Illinois, and Indiana suggested separating BC and FM into two grade factors. Managers of interior elevators generally supported the separation of BCFM into two components; 46.6 percent gave positive opinions, 31.5 percent gave negative opinions, and 21.9 percent were indifferent.

Managers of export elevators were about equally divided among positive, negative, and indifferent attitudes toward separating the factor of BCFM into two components.

The only significant explanatory variable associated with the managers' attitudes toward separating BC and FM was the percentage of their shipments that had received discounts for BCFM in the past. Those elevators reporting the higher percentage of shipments receiving discounts were most supportive of the idea of separating the factor of BCFM.

Conclusions

Separation of BC and FM based on sieve size segregates broken corn into different categories according to particle size. Costs of inspection and segregation would be increased if the industry adopted two grade factors instead of one. Chemical analysis shows relatively small differences and no obvious breakpoint for choosing the optimum sieve size. However, there is a major difference in the power required for aerating corn in bins between the smaller particles and larger particles in the corn mass. Therefore, the greatest incentive for removing smaller particles of broken corn from larger particles lies in the reduced cost of maintaining the quality of corn held in storage.

Creating two grade factors of BC and FM (both primarily comprised of broken corn) differentiated only on the basis of particle size provides little additional information about the value of the lot, while increasing the cost of grading, segregation, and blending.

Separating BCFM into two grade factors will not, by itself, induce significant changes in management practices. Improved quality for export can be achieved only by lowering grade limits for BC, FM, or both, at significantly increased costs of cleaning. In addition, the separation of BCFM into two factors will increase segregation costs. Given the design of current cleaners, BC and FM will continue to be included in corn screenings. The difficulty of separating the two in commercial cleaners, plus problems of handling and storing FM (particles smaller than 6/64-inch), would be major deterrents to marketing BC and FM as separate commodities.

Farmers may perceive two factors in place of one as increasing the opportunity for buyers to assess additional discounts. The authors have concluded that a redefinition of BCFM without any change in grade limits will generate additional costs with little benefit and no improvement in quality.

Lower limits on BCFM will reduce both BC and FM, with FM being reduced proportionally more than BC under current cleaning technologies and strategies. Lower limits on only FM will have the same effect as a lower limit on BCFM because current cleaning technology at most elevators will not remove fines without also removing BC. Changing cleaning strategies to remove only FM will require major investments in retrofitting or replacing current systems.

Limits on fines or FM, less than the percentage created during handling, will significantly increase cleaning costs because creation of fines during handling will result in cleaning (or discounts) at each point in the market channel. The impact on destination quality will be small because loading and unloading in the ports will create enough fines and dust to exceed the grade limit.

The separation of samples into CFM and BC increases information for determining value and does not require any additional segregation or blending in the market. Cost of grading will increase as a result of a second sieve or riddle and the time required to weigh and record CFM. The quantity of material to be removed (or docked) will be a very small proportion of the total grain delivered. Non-corn material larger than 12/64-inch but small enough to pass through the scalper will be included as corn.

Although the percent of weight removed as CFM is small (0.1 to 0.3 percent), total tonnage of CFM multiplied by transport cost and by the delivered price paid for the shipment results in significant cost reductions if the CFM is removed at the farm. In addition, the quality perception of foreign buyers is heavily influenced by the readily observed CFM in the vessel.

Unlike BC, the quantity of CFM will not increase during handling in the market channel. Once CFM is removed from the grain at the farm or country elevator, there is no legal way for additional CFM to enter the market channel.

Adding an additional factor to measure the percentage of CFM separate from the percentage of BC is consistent with the grades of the major competing exporting countries that identify non-corn material as impurities.

Benefits are difficult to quantify but can be described for consideration. Identifying the quantities of BC and CFM in the corn samples provides additional information for use by the buyer. Quality improvement will depend on actions by managers in response to market incentives. Increased value resulting from small reductions in BCFM will be difficult to detect in the plant of the foreign buyer. Higher values will gradually be incorporated into the base price, but the effect may be concealed by the many other influences on price. Increased value at destination will be achieved only if the inherent resistance to breakage is incorporated as part of producer incentives.

The results of this study suggest that only two or three alternative formulations of the BCFM factor in corn grades will lead to higher-valued corn in the export market channel at a cost commensurate with benefits. The issue of redefining the factor of BCFM in corn grades was expanded during conduct of the study to include BCFM-related strategies for improving corn quality.

Incentives for changing practices to prevent breakage will always be a more efficient and cost-effective means of improving quality than efforts to remove or reduce the broken kernels following each handling and impact in the market channel.

Changes in grades should be approached as a system where uniform terminology providing accurate description of economically important characteristics increases the efficiency of the market in the aggregate. No single grade factor can be demonstrated to alter export volume, market shares in world markets, farm income, or base price for corn. Changes in grade factors must be justified on the basis of their value and contribution to the total system rather than on their individual costs and benefits.

Recommendations

1. Breakage susceptibility should be included as a non-grade standard to be reported in all official inspections. Federal Grain Inspection Service research efforts should be directed toward the development of a practical test for breakage susceptibility. A temporary measure such as percentage of kernels with stress cracks should be introduced while a range of tests and technologies are explored and a more objective and automated procedure is developed. The precision of the test should allow identification of two or three categories of quality rather than developing a continuous scale for setting price differentials.

Justification. Reducing breakage susceptibility will be a much more cost-effective method of reducing the levels of BCFM in the market channel than separating the grade factor into BC and FM on the basis of particle size or lowering the grade limit. Reducing breakage susceptibility will not only reduce the levels of BCFM in the market channel but also dramatically improve the intrinsic quality for most end uses, reduce the amount of dust in the export channel, and put the responsibility for quality improvement back at the farm where the producer can control variety, harvesting methods, and drying technology. If grades and the market price differentiate low-breakage corn from corn that has been dried at high temperatures or damaged in harvesting, the average quality of corn will be improved throughout the market channel, and value in use will be increased.

2. Grade definitions should include dockage designated as CFM, defined as non-corn material that can be readily removed by mechanical scalping. The factor should have a base level of zero and be rounded to the nearest tenth. The specific definition, including configuration of the sieve for separation, should be developed by the Federal Grain Inspection Service (FGIS).

Justification. Separation of BCFM into coarse broken corn and finely broken corn (the concept of BC and FM in current definitions) does little to identify differences in value.

The screen size selected is arbitrary, and the difference in value from one particle size to the next is generally insignificant. Separating CFM from broken corn and fines increases the information for determining value, adds little to the cost of grading, and does not require segregation or blending in the market. Unlike broken corn, the quantity of CFM will not increase during handling in the market channel. Once CFM is removed at the farm or country elevator, there is no legal way for additional CFM to enter the market channel.

The definition suggested for CFM approximates current scalping practices in the industry, not the hand-picked CFM as defined in the current corn grades. The quantity of material to be removed will be a very small proportion of the total grain delivered, so there will be little economic burden on producers. Although the removal of the small amount of CFM will have only a small effect on actual quality and value, there will be a direct impact on the foreign buyers' perception of quality. Buyers frequently complain about receiving low-value CFM and the cost of transporting and purchasing it. The proposed definition of CFM is similar to the definition of impurities used in the grades of the major exporting countries with which the United States competes.

3. The current factor of BCFM should be replaced with the factor Total Broken Corn (TBC), defined as all material passing through the 12/64-inch sieve. The limits on this factor for each grade should be one percentage point less than the current limits on BCFM, assuming that a breakage susceptibility test is simultaneously introduced.

Justification. The decreased value of BC for most uses is independent of the particle size. Any broken kernel has a lower value than a whole kernel for most purposes, including storage and handling. There are no mechanical methods for identifying whole, unbroken kernels (although that may be a future goal in development of test equipment). The use of the 12/64-inch sieve does not provide a complete separation of whole and broken kernels, but it is an acceptable compromise since it can be accomplished mechanically and requires no change in current grading methods. The lower grade limits (if adopted) could create additional incentives to adopt varieties, technologies, and management strategies to reduce breakage susceptibility. Once these have been adopted by farmers and grain handlers, the levels of TBC will be reduced throughout the market channel and the lower limits can be met without additional cleaning.

4. FGIS should develop a master plan that includes a set of ideal grades and a strategy for implementing future changes so as to minimize adjustment costs to the industry.

Justification. Changes in grades should not be introduced or evaluated one factor at a time. The value of grades derives from having a uniform system to describe value for use in commercial trade. FGIS should develop a set of ideal grades designed to meet the purposes stated in the Grain Standards Act. The ideal can be used to develop a plan for moving toward a system that will enhance quality and marketing efficiency while minimizing disruption in the industry. Recommendations 1 through 3 can contribute toward the ideal grades by providing more information about end-use value, creating incentives for quality improvement, and increasing equity among sellers who deliver corn of varying qualities.

Evaluating the Aggregate Costs and Benefits of Separating Broken Corn and Foreign Material

The costs associated with corn breakage, coupled with complaints of foreign buyers, have generated interest in finding economically viable methods to reduce the amount of broken corn and foreign material in market channels. Legislation to reduce foreign material through prohibition of blending or mandated cleaning has focused on improving the image of U.S. corn in overseas markets, rather than on the information provided by grades and quality factors. One of the more important definitional issues in developing and using grades is the differentiation between whole kernels, broken kernels, and non-corn material.

Corn grades in Argentina, Yugoslavia, Thailand, and South Africa define impurities as non-corn material handpicked from the sample before sieving for broken corn. Broken corn is based on particle size. In contrast, current U.S. grades do not make this distinction. Hand-picked non-corn material is combined with material passing through a 12/64-inch sieve into one factor called "broken corn and foreign material" (BCFM). However, Federal Grain Inspection Service (FGIS) regulations implementing the 1986 Grain Quality Improvement Act provided separate definitions for broken corn (BC) and foreign material (FM) and required the information to be recorded separately on inspection certificates while leaving the combined factor BCFM in the corn grades [*Federal Register,* 1987].

History of Changes in BCFM

The debate over the best definition of non-corn material and appropriate measurement technology predates the original legislation authorizing a national system of grain grades. In the grades for corn proposed by the Grain Dealers National Association in 1908, dirt and broken grains were combined into one grade-determining factor ["New Inspection Rules," 1908].

The 1914 voluntary grades for corn contained two factors related to non-corn materials: (1) foreign material, which included dirt, pieces of cob, other grains, finely broken corn, etc. (where finely broken corn was defined as material passing through a 9/64-inch, round-hole sieve); and (2) cracked corn, which included all the broken kernels passing through a 16/64-inch sieve except finely broken corn [Duvel, 1915].

When the mandatory corn grades were promulgated in 1916, following passage of the Grain Standards Act, a 14/64-inch sieve was adopted because of widespread public opposition to the use of two sieves, and the two grade factors were combined into "cracked corn and foreign material" (CCFM) ["Corn Sieves," 1937]. In 1921, the USDA substituted a 12/64-inch sieve because of charges that the use of the 14/64-inch sieve lowered the grade of high-temperature kiln-dried corn, even though such corn met consumer demands and warehouse requirements ["Corn Sieves," 1937].

By 1930, complaints against the 12/64-inch sieve prompted the Chief Grain Inspector to pass a resolution requesting a change to a 10/64-inch sieve ["Annual Meeting," 1930]. The clamor for using this smaller sieve peaked when high rainfall forced the trade to kiln-dry an abnormally large percentage of the 1935 crop. Several other trade organizations joined the call for using a 10/64-inch sieve to separate CCFM in order to salvage pieces of corn classified as CCFM by the 12/64-inch sieve.

A special committee of the Chicago Board of Trade argued for the use of the 10/64-inch sieve and recommended installing a second sieve with a special limit for fines and dust. The USDA's Bureau of Agricultural Economics argued against the use of the 10/64-inch sieve on the grounds that it would have a negative impact on storability. However, results of actual handling tests conducted by the industry and the USDA showed that changing to the 10/64-inch sieve and leaving larger pieces of corn in the clean-corn fraction would have little detrimental effect on the storability or value of the corn [Hill, 1990].

Farmers and grain dealers appeared to favor the change to the 10/64-inch sieve. According to the editor of *The Grain Dealers Journal,* "The farmers, the country shippers and the terminal elevator men want the 10/64-inch sieve to the end that the larger and valuable pieces of broken corn may be included with the corn when grading with the important improvement on the present system of sieving out the fine flour that is objectionable" ["Changes in Grain," 1937].

In 1937, the annual convention of the Farmers Grain Dealers Association of Illinois approved the proposed change to a two-sieve definition coupled with the use of a 10/64-inch sieve instead of the 12/64-inch sieve ["Illinois Farmer Dealers," 1937]. "The farmers producing the corn and the central market dealers warehousing the corn seem to have made out a good case for the desired change in the perforations of the sieve used in grading corn. The smaller, 10/64-inch opening will retain more of the valuable larger pieces of broken kernels to go into the higher grades. The farmer's interest is two-fold. First, he gets more feed value; and second, the buyer of his corn can afford to pay more for it by about 2 percent" ["Change in Corn," 1937].

In spite of farmer support, the Grain Division of the USDA's Bureau of Agricultural Economics was responsive to the opposition voiced by corn users and merchandisers who did not want more broken kernels classed as corn, and the 12/64-inch sieve was retained.

Attempts to redefine "broken corn and foreign material" were renewed in the late 1970s. In February 1976, the USDA's Agricultural Marketing Service proposed eliminating BCFM as a grading factor and substituting three factors in its place: (1) "Broken corn and small kernels" would be all material passing through a 15/64-inch round-hole sieve but remaining on top of an 8/64-inch round-hole sieve; (2) "screenings" would include all material passing through an 8/64-inch round-hole sieve; and (3) "foreign material" would include all matter other than corn remaining on top of an 8/64-inch round-hole sieve [USDA, 1976]. This idea was presented at hearings in several locations around the United States but generated so much opposition from the grain industry that the proposal never reached the *Federal Register*. The major objections concerned measurement difficulties, higher grading costs, potential losses for producers through a reduction in the amount of BCFM that could be sold as corn, and possible effects on the pricing structure in foreign markets.

Redefinition of BCFM

During the past 10 years, several alternative proposals have been reviewed for redefining the materials classified as broken corn and foreign material. The most widely accepted proposal came from the Grain Quality Workshop (GQW), sponsored by the North American Export Grain Association. That committee cautiously reported in favor of separating BC and FM in the corn grades in their 1986 report to Congress, *Commitment to Quality*. Their specific proposal was the following:

> In concept, broken corn and foreign material should be separated for grading purposes, subject to supportive results from an in-depth impact study by FGIS, industry and academia, the study to begin immediately. The fraction of a corn sample passing through a 12/64-inch round-hole screen, but not through a smaller screen (either an 8/64-inch or 6/64-inch round-hole) would be a grade determining factor, broken corn (BC). Grade levels for BC should be set consistent with the objective of increasing corn value. The portion passing through the smaller screen, plus coarse handpicked foreign material would be a non-grade determining dockage (discount) factor,

similar in concept to wheat dockage, and listed on the certificate to the nearest 0.1 percent [North American Export Grain Association, 1986].

U.S. Grades and Standards define BCFM on the basis of particle size; BCFM consists of all material passing through the 12/64-inch round-hole sieve. However, this definition does not provide an accurate distinction because the "whole corn" portion of the sample contains some broken kernels, and some small whole kernels pass through the sieve. In 1988, FGIS adopted the 6/64-inch distinction between BC and FM as proposed by GQW and required the relative amounts of BC and FM to be included in the remarks section of all official certificates except export certificates. The following definitions were used:

Broken corn (BC) is all material passing through a 12/64-inch sieve, but not a 6/64-inch sieve. FM is all material passing through a 6/64-inch sieve plus non-corn material hand-picked from on top of the 12/64-inch sieve. BC and FM are listed as information but do not establish numerical grade. Their summation, BCFM, is still the grade-determining, particle-size factor for corn.

The impetus for separating the BCFM grade factor came from several sources: (a) foreign complaints, (b) congressional concern about lost market share, (c) commodity groups concerned over equity in payments for different qualities, and (d) the poor image of U.S. corn among international buyers. Thus, the primary focus in the requests for change has been the export market channel. Excess BCFM increases storage and processing costs and reduces the value of corn in the domestic market as well, but few domestic processors or merchandisers have pressured Congress or FGIS for change.

Properties of Corn Screenings

Review of Previous Studies

Hill et al. [1982] analyzed 1,080 samples of corn from Illinois country elevators and subterminals in 1976 and 1977. Table 1 lists constituents found in these samples, along with their size distribution. The material (corn, weed seeds, corn by-products, and inert material and dust) in each size category was determined by visual examination, with the aid of a low-power magnifying glass.

Even the smallest size particles were primarily corn. Most non-corn material in the samples (58 percent by weight) was in the material passing through the 10/64-inch sieve. The material passing through the 12/64-inch sieve contained 69 percent of the non-corn material. Non-corn material on top of the sieve 12/64-inch sieve would have been graded as coarse FM and included as BCFM under current grades.

Several studies have reported the distribution of fines of various sizes in market corn. These data are summarized and averaged in Table 2 [Bern and Hurburgh, 1992]. The percentage passing through a 12/64-inch round-hole sieve is used as the reference weight. Amounts passing through other sieve sizes are expressed as percentages of the weight passing through the 12/64-inch sieve. As an example, on average, 19.2 percent of what is now BCFM would pass through a 6/64-inch sieve. The remaining 80.8 percent of BCFM was between the 12/64-inch and 6/64-inch sieves and would be classified as BC under the proposed redefinition. The relative concentration of various particle sizes remained constant through the market channel even though the actual level of fines increased steadily with repeated handling. For example, export lots were consistently higher in BCFM than country elevator lots, but their relative concentrations in each of the particle sizes were not similar.

The average level of BCFM delivered to country elevators was less than 2 percent in the 1976 and 1977 study. Other studies have found the same low concentrations of BCFM at country elevators [Hurburgh and Moechnig, 1984; Hurburgh et al., 1983; Hurburgh, 1984].

Estimating Particle-Size Distributions

The particle-size distribution of market corn is important information for estimating the effect of alternative definitions of BCFM on the

Table 1. Constituents and Size Distribution of 1976 and 1977 Corn Samples Delivered to Illinois Country Elevators and Subterminals

	Particle size[a]						
	Whole corn (>15/64-in.)	6.0 mm (15/64-in.)	4.8 mm (12/64-in.)	4.0 mm (10/64-in.)	3.2 mm (8/64-in.)	2.4 mm (6/64-in.)	1.8 mm (4.5/64-in.)
Corn[b] (%)	99.95	98.31	96.50	91.98	89.10	85.24	77.61
Corn by-products[c] (%)	0.03	1.02	2.60	5.06	8.09	12.99	20.47
Weed seeds (%)	0.02	0.66	0.88	2.96	2.42	0.90	1.73
Dust and inert material (%)	0.00	0.02	0.03	0.03	0.38	0.87	0.29
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total non-corn material (% of total)	17	13	11	16	13	8	21

Source: Hill et al., 1982.

[a]Size of particles in each category lies between that screen size and the next smaller one; [b]Includes whole corn and large pieces of broken corn remaining on top of the 15/64-in. sieve; [c]Non-kernel material originating on corn plant.

Table 2. Summary of Data on Corn Fines Size Distribution

Data source (reference)*	Percentage through 4.8 mm (12/64-in.)	*Material through sieves, as a % of that through 4.8-mm (12/64-in.) sieve* 6.4 mm (16/64-in.)	6.0 mm (15/64-in.)	5.6 mm (14/64-in.)	4.8 mm (12/64-in.)	4.0 mm (10/64-in.)	3.2 mm (8/64-in.)	2.4 mm (6/64-in.)	1.8 mm (4.5/64-in.)	1.2 mm (3/64-in.)
Export shipments, 1974-75 (a)	3.28	246.5			100.0			21.5		6.4
Country elevator receipts, 1975, IA (b)	1.24		301.6		100.0		41.9			
Country elevator receipts, 1976 IA (b)	1.64		259.8		100.0		39.0			
Country elevator shipments, 1975, IA (b)	1.89		267.2		100.0		31.2			
Country elevator shipments, 1976, IA (b)	2.05		256.1		100.0		37.1			
River terminal receipts, 1975, IA (b)	1.32		285.5		100.0		34.8			
River terminal receipts, 1976, IA (b)	1.54		278.6		100.0		35.7			
River terminal shipments, 1975, IA (b)	1.75		282.9		100.0		39.4			
River terminal shipments, 1976, IA (b)	2.40		265.4		100.0		52.9			
Export receipts by barge, 1975 (b)	2.71		237.6		100.0		41.7			
Export receipts by barge, 1976 (b)	3.08		229.2		100.0		40.9			
Export receipts by unit train, 1976 (b)	2.74		255.1		100.0		31.4			
Export shipments, 1975 (b)	3.12		240.7		100.0		36.2			
Export shipments, 1976 (b)	3.33		230.0		100.0		39.9			
Country elevator receipts, 1976-77, IL (c)	1.14		247.4		100.0	54.3	34.2	19.2	12.3	
Country elevator shipments, 1976-77, IL (c)	1.85		211.9		100.0	50.3	31.9	17.8	11.4	
Terminal receipts, 1976-77, IL (c)	2.00		196.5		100.0	63.1	36.0	20.5	13.1	
Terminal shipments, 1976-77, IL (c)	2.60		181.5		100.0	64.6	36.9	19.6	12.3	
Export shipments, 1978-79 (d)	3.30				100.0		33.3		12.1	
Country elevator shipments, 1981 (e)	2.25	243.9		163.4	100.0	56.1	31.7	19.5	12.2	
Export shipment sublots, 1985 (f)	5.32	266.9			100.0	44.1	39.3	19.9		5.3
Hopper cars at origin, 1986, IA (g)	2.11	273.5		152.1	100.0	62.1	29.8	16.1		
River terminal shipments, 1986, IA (g)		213.6		139.9	100.0	60.7	33.4	18.5		
Average	**2.39**	**248.9**	**248.6**	**151.8**	**100.0**	**61.6**	**36.8**	**19.2**	**12.2**	**5.8**

*Reference key: a = Hill et al., 1979; b = Iowa Development Commission, 1977; c = Hill et al., 1982; d = Hill et al., 1981; e = Grama et al., 1984; f = Hill et al., 1985; g = Hurburgh, 1986.

amount of material classed as discountable. Equations (1), (2), and (3) were derived from the data of Table 2 for estimating the percent of the sample passing through a sieve of any size.

Data provided by the FGIS were used to test the validity of the prediction equations and to determine if particle size distributions were correlated with any other grade factors. FGIS provided data on all grade and condition factors according to the new definitions of BC and FM from both export and domestic inspections.

$$Z_{B,S_i} = e^{0.265S_i + 1.455} \qquad (1)$$

where

Z_{B,S_i} = the percentage of total sample weight that would pass through a round-hole sieve of size s_i

s_i = the size of the round-hole sieve used in separation, recorded in 64th inches, and $3 \leq s_i \leq 16$

The percentage of the total sample weight that would pass through any round-hole sieve is then

$$Z_{T,S_i} = \frac{Z_{B,S_i}}{100} B \qquad (2)$$

Table 3. Corn Inspection Data

		Number of observations	
Variable	Source	1988-89	1989-90
Type	Supervision[a]	15,617	15,410
	Appeal[a]	5,718	2,342
	Export original	1,819	2,049
Movement[a,d]	Inbound	1,757	1,861
	Outbound	10,447	10,159
	Local	21	14
	Submitted	3,392	3,376
Carrier[d]	Truck[a]	1,112	1,409
	Hopper car[a]	8,618	8,394
	Barge[a]	2,488	2,221
	Other[a,b]	3,399	3,386
	Vessel[c]	1,819	2,049

[a]Domestic corn only; [b]Submitted samples plus other carriers; [c]Export only; [d]Appeals eliminated.

where

B = the percent BCFM, using the FGIS definition of 12/64-inch sieve

The percentage of the total sample between any two screen sizes, s_1 and s_2, is

$$Z_{T,S_1} - Z_{T,S_2} = (Z_{B,S_1} - Z_{B,S_2}) \frac{B}{100} \qquad (3)$$

where

Z_{B,S_1} and Z_{B,S_2} are calculated from equation 1.

Export data were taken from the Export Grain Inspection System (EGIS) database. There were 1,819 export lots certified in 1988–89 and 2,049 lots certified in 1989–90 (Table 3). Interior inspection data were obtained from the Grain Inspection Monitoring System (GIMS) database. Two types of inspections are recorded: (1) appeals of interior-agency original inspections to FGIS field offices and (2) field-office supervisory monitoring random samples of 0.5 percent of interior-agency inspections. Appeal data were not used in this analysis because they are not representative of inspections as a whole.

The particle size factors identified as FM and BCFM were measured directly by inspectors. BC was calculated by subtracting the FM percentage from the BCFM percentage. The coarse FM (non-grain material larger than 12/64-inch) was included with FM. Any non-grain material falling through the 12/64-inch screen but not the 6/64-inch screen was included in the BC fraction. The FM ratio, percent FM divided by percent BCFM, was calculated for each observation. The predicted FM ratio is the solution of equation (1), with s_i = 6/64-inch.

Statistical Analysis

For export corn, averages and standard deviations for all grade factors and the FM ratio were calculated by year and grade. Paired t-tests were used to determine if the FM ratio was significantly different between grades ($p = 0.05$), and if the measured FM ratios were different from those predicted by equation (1). Mean values of all numeric variables, by grade, for the two years were tested for significant differences.

The domestic inspection data were sorted by year, carrier, and grade. Boxcar samples ($N = 7$) and "other carrier" category were not used for analysis. Carrier designation was not available for submitted samples. There were no significant differences between inbound and outbound inspection data by grade and carrier. Therefore, no variable was included to identify inbound versus outbound shipments. Statistical comparisons were made among grades, carriers, and years.

A correlation matrix was formed with all the quality test variables and the FM ratio. Export and domestic data were combined, to test the effect of other quality factors on the relative amounts of BCFM and FM in corn lots. Separate correlation coefficients were calculated for each year.

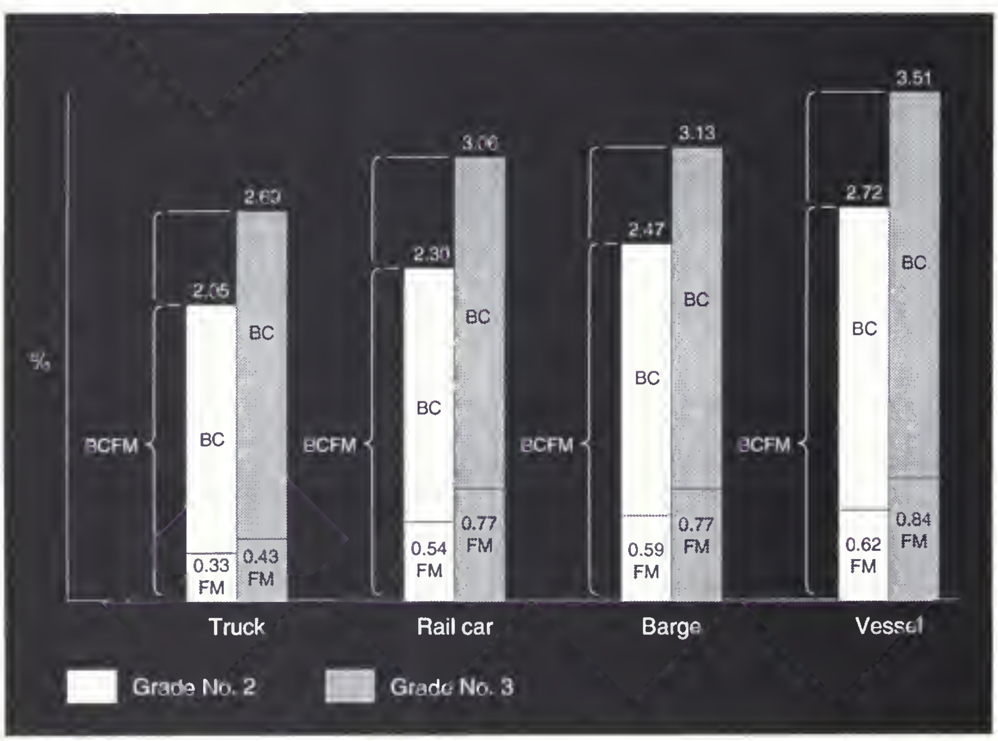
Tables 4 and 5 give the averages for grade factors along with the number of samples and volume (export data only). The data were divided by carrier (vessel, barge, hopper car, and truck) and by grade (1 to 5 and Sample). Appeal samples, samples with incomplete data (factor-only inspections), and submitted samples (carrier not known) were eliminated.

Average quality of the lots sampled deteriorated from predominantly No. 1 and No. 2 yellow corn at inland points to No. 3 yellow corn at export locations. There was a steady decline from truck to hopper car to barge and finally to vessel. This decline was almost exclusively due to BCFM increases, not to reduction in test weight or increases in damage.

Table 6 relates percent FM to percent BCFM, by grade, carrier, and year. There was a slight trend of an increasing FM ratio with increasing BCFM in all carriers except vessels. There was also a small but significant difference between 1988–89 and 1989–90 data, 1989–90 being higher. The difference has no practical significance since the actual change in the FM level for a 1-unit change in the FM ratio was only 0.03 percentage points of FM.

Trucks were the only carrier with an FM ratio significantly different from other carriers (Figure 1). This is logical because truck grain is handled less, blended less, and therefore of a quality closer to field-run than grain in any of the other carriers. BCFM in truck samples was not as close to grade limits as samples

Figure 1. BCFM and FM in No. 2 and No. 3 corn by carrier, 1989–90.



from the other carriers. As would be expected, shiplot samples were the closest to the grade limits, followed by barge samples, hopper car samples, and truck samples. BCFM was the only factor that changed noticeably by carrier and was the only factor that consistently approached grade limits. This suggests that regardless of how BC and FM are defined with respect to particle size, exporters will feel the most pressure.

Relationship Between Particle Size and Grade Factors

The FM ratio increased slightly with BCFM concentration for three of the four carrier types. Table 7 shows the regression equations of FM ratio against BCFM. None of the coefficients was significant at $p = 0.05$. The slopes (rates of change of FM ratio) were not large. The R^2 values, while statistically significant, were very low, which indicates that the regression equations are not very useful for predicting individual situations. From a practical viewpoint, the mean value of the FM ratio is nearly as good as the regression equations for estimating future FM values.

No other grade factor was strongly related to either FM ratio or percent BCFM, as shown in Table 8. These data fail to support claims that low test weight is indicative of breakage-prone or moldy corn, or both. Since differences in test weight can be caused by many genetic and condition characteristics [Hall and Hill, 1973], it is not a good predictor of BCFM and damage (DKT) levels. Blending and cleaning cause BCFM and DKT to be independent of other quality characteristics.

Table 4. Corn Quality by Carrier and Grade, 1988–1989

Carrier origin	Grade	MC (%)	TW (lb/bu)	DKT (%)	BCFM (%)	Number of lots	Volume (tons)
Vessel (export)	1	13.6	58.5	1.6	1.6	16	69,212
	2	13.7	57.0	3.6	2.8	550	13,723,471
	3	13.7	57.0	4.9	3.7	1,224	37,539,488
	4	14.0	56.4	4.4	4.3	13	53,025
	5	13.8	57.6	3.4	5.5	7	32,790
	Sample	13.7	57.3	2.7	3.1	9	63,990
Average shiplots		**13.7**	**57.0**	**4.5**	**3.4**	**1,819**	**51,481,976**
Barge[a] (interior)	1	13.8	57.7	2.1	1.6	139	
	2	13.5	57.0	3.7	2.5	947	
	3	13.4	56.9	4.8	3.3	986	
	4	13.4	56.8	6.2	3.9	269	
	5	13.2	56.7	7.8	4.8	115	
	Sample	12.9	56.4	14.9	5.2	23	
Average barges		**13.5**	**57.0**	**4.6**	**3.1**	**2,479**	
Hopper car[a] (interior)	1	13.8	57.5	2.1	1.6	1,095	
	2	13.6	57.0	3.5	2.3	3,585	
	3	13.6	56.8	4.7	3.0	1,964	
	4	13.6	56.7	6.2	3.7	720	
	5	13.6	56.5	9.1	4.4	334	
	Sample	13.6	56.2	15.0	6.1	138	
Average hopper cars		**13.6**	**57.0**	**4.3**	**2.7**	**7,836**	
Truck[a] (interior)	1	13.7	58.1	1.9	1.3	369	
	2	13.4	57.3	3.4	2.2	287	
	3	13.3	56.9	5.0	2.8	174	
	4	13.1	57.1	7.4	3.1	139	
	5	13.0	56.6	9.6	4.1	83	
	Sample	13.2	56.6	14.8	5.8	58	
Average trucks		**13.4**	**57.4**	**5.8**	**2.5**	**1,110**	

MC = moisture content; TW = test weight; DKT = total damage; BCFM = broken corn and foreign material.

[a]Appeals and factor-only inspections eliminated.

Buyers' Estimates of Corn Screenings Composition

In a survey of buyers of corn screenings, respondents estimated the percentage of their screenings composed of three types of matter: broken corn, other grains, and non-grain material. Respondents' estimates of corn screenings composition were 80 to 90 percent corn, 0 to 8 percent other grains, and 0 to 15 percent non-grain materials. A previous study [Hill et al., 1982] reported the composition of BCFM in corn received from country elevators as 92.7 percent corn; 0.1 percent dust and inert; 0.7 percent weed seeds and other grains; and 6.6 percent corn by-products (Figure 2). The opinions of screenings buyers about the proportion of corn in BCFM is consistent with the results from the laboratory analysis.

Figure 2. Composition of BCFM at country elevators.

Table 5. Corn Quality by Carrier and Grade, 1989–1990

Carrier origin	Grade	MC (%)	TW (lb/bu)	DKT (%)	BCFM (%)	No. of lots	Volume (tons)
Vessel (export)	1	13.8	57.6	1.4	1.5	17	89,863
	2	14.1	57.0	2.7	2.7	265	18,698,938
	3	14.2	56.9	3.0	3.5	1,258	40,287,484
	4	13.8	57.1	4.3	4.3	1	1,271
	5	—	—	—	—	0	—
	Sample	14.1	57.4	3.9	3.5	8	43,196
Average shiplots		**14.1**	**57.0**	**2.9**	**3.2**	**2,049**	**59,120,752**
Barge[a] (interior)	1	14.2	57.4	2.0	1.7	699	
	2	14.1	57.2	2.8	2.5	1,040	
	3	13.8	56.9	4.0	3.1	376	
	4	13.7	56.9	6.2	3.6	73	
	5	13.6	57.2	7.1	4.6	17	
	Sample	12.9	56.9	10.1	8.5	8	
Average barges		**14.0**	**57.2**	**3.1**	**2.6**	**2,213**	
Hopper car[a] (interior)	1	14.1	57.6	1.7	1.6	2,917	
	2	14.2	57.0	2.7	2.3	3,182	
	3	14.2	56.8	3.9	3.1	1,403	
	4	14.0	56.6	5.4	3.7	486	
	5	14.0	56.4	7.0	4.7	181	
	Sample	13.9	54.3	15.1	6.5	62	
Average hopper cars		**14.1**	**57.1**	**3.0**	**2.5**	**8,231**	
Truck[a] (interior)	1	14.2	58.3	2.2	1.3	1,013	
	2	14.2	36.9	3.4	2.1	177	
	3	14.0	57.1	4.9	2.7	88	
	4	14.2	56.9	7.1	2.8	63	
	5	13.5	57.2	8.9	4.3	37	
	Sample	12.6	57.7	13.6	7.9	24	
Average trucks		**14.1**	**57.9**	**5.4**	**2.6**	**1,402**	

MC = moisture content; TW = test weight; DKT = total damages; BCFM = broken corn and foreign material.

[a]Appeals and factor-only inspections eliminated.

Table 6. Particle Size Distribution by Carrier and Grade

Carrier origin	Grade	1988-89 FM (%)	1988-89 BCFM (%)	1988-89 FM ratio (%)	1989-90 FM (%)	1989-90 BCFM (%)	1989-90 FM ratio (%)
Vessel (export)	1	0.44	1.59	27.9	0.39	1.51	25.6
	2	0.59	2.75	21.5	0.62	2.72	22.7
	3	0.82	3.70	22.2	0.84	3.51	24.0
	4	1.02	4.28	24.8	1.00	4.30	23.3
	5	1.09	5.54	19.7	—	—	—
	Sample	0.72	3.08	24.7	0.98	3.53	28.1
Average shiplots		**0.75**	**3.40**	**22.1**	**0.76**	**3.20**	**23.5**
Barge[a] (interior)	1	0.39	1.63	23.6	0.40	1.66	24.0
	2	0.60	2.49	23.8	0.59	2.47	23.9
	3	0.82	3.32	24.6	0.77	3.13	24.4
	4	0.99	3.90	24.8	0.92	3.62	25.0
	5	1.27	4.78	26.1	1.08	4.62	22.7
	Sample	1.42	5.16	26.9	2.14	8.46	25.2
Average barges		**0.77**	**3.09**	**24.4**	**0.62**	**2.56**	**24.1**
Hopper car[a] (interior)	1	0.31	1.56	19.1	0.33	1.55	21.2
	2	0.46	2.27	20.2	0.54	2.30	23.2
	3	0.65	2.97	21.6	0.77	3.06	24.6
	4	0.88	3.66	23.3	0.97	3.69	25.4
	5	1.10	4.42	24.3	1.29	4.66	26.3
	Sample	1.65	6.09	25.9	1.98	6.45	27.5
Average hopper cars		**0.58**	**2.66**	**21.0**	**0.59**	**2.45**	**23.2**
Truck[a] (interior)	1	0.22	1.32	16.3	0.26	1.30	22.1
	2	0.36	2.23	16.4	0.33	2.05	16.4
	3	0.48	2.83	17.1	0.43	2.69	16.4
	4	0.61	3.11	18.8	0.51	2.82	17.9
	5	0.79	4.13	18.8	0.92	4.28	19.9
	Sample	1.46	5.81	22.6	1.65	7.87	20.0
Average trucks		**0.46**	**2.49**	**17.3**	**0.49**	**2.64**	**18.3**

FM—foreign material; BCFM—broken corn and foreign material.

[a]Appeals and factor-only inspections eliminated.

Table 7. Regression Equations of FM Ratio Against BCFM Percentage, by Carrier

Carrier	Average FM ratio (%)	Regression coefficients A	Regression coefficients C	R^2 (%)	Standard deviation (% points)
Truck	17.6	0.67	15.9	1.5	9.4
Hopper car	22.1	1.73	17.7	6.6	7.4
Barge	24.2	0.81	21.9	1.6	5.9
Ship	22.8	0.03	22.7	0.0	5.3
All carriers	22.4	1.40	18.5	4.6	7.1
Predicted from equation 1	20.7	—	—	—	—

FM = foreign material; BCFM = broken corn and foreign material. The regression equation was FM ratio = C + A (percent BCFM), where C is the intercept term and A is the regression coefficient for the variable BCFM. FM ratio is defined as (percent FM/percent BCFM) × 100.

If cleaning practices were altered to remove only the smaller particle sizes classified as FM in the proposed redefinition, the composition of corn screenings would be altered. Survey respondents were asked to estimate the effect on screenings composition if a smaller screen were used for cleaning corn. Specifically, respondents were asked whether they would expect the following characteristics to increase or decrease if the sieve size for defining screenings were reduced: test weight, energy level, fiber content, protein content, and feed value. Respondents disagreed about the effect on fiber; 33 percent said fiber content would increase and 30 percent said fiber content would decrease if

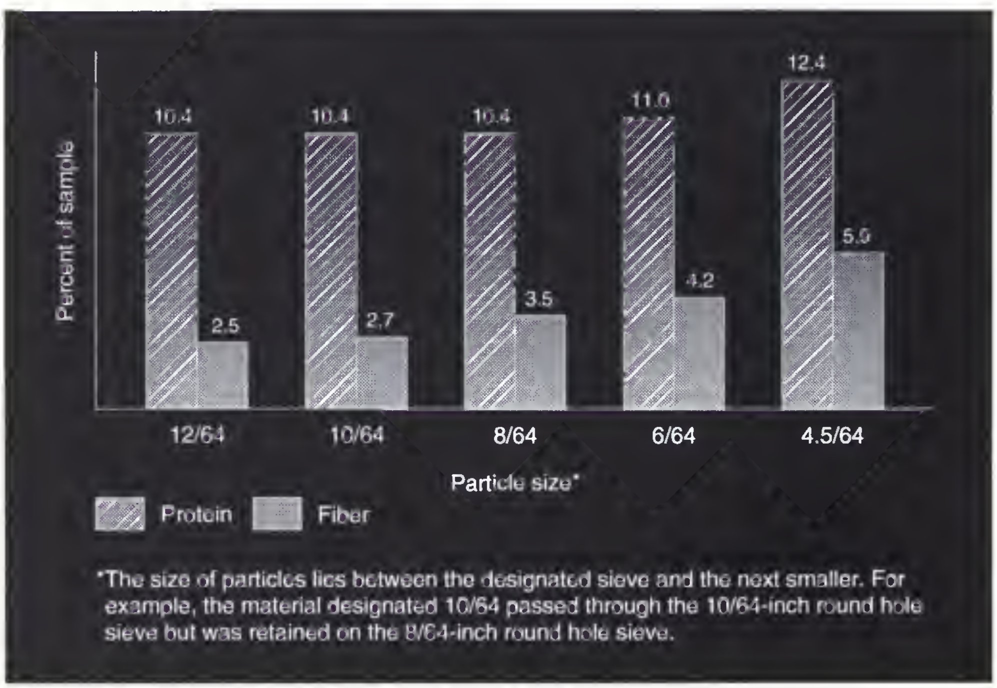
Table 8. Correlation Coefficients (r) Among Corn Grade Factors and FM Ratio, 1988–89 and 1989–90 Data

	1989–90						
1988-89	TW	MC	HT	DKT	BCFM	FM	FM ratio[a]
TW	1	NS	NS	NS	NS	NS	NS
MC	NS	1	NS	–0.20	NS	NS	NS
HT	NS	NS	1	0.35	NS	NS	NS
DKT	–0.22	NS	0.20	1	0.21	NS	NS
BCFM	NS	NS	NS	0.20	1	0.84	0.23
FM	NS	NS	NS	NS	0.85	1	0.61
FM ratio	NS	NS	NS	NS	0.27	0.61	1

All listed coefficients were significant at the 0.05 level. NS = not significant or <0.2. Appeals, submitted samples, and factor-only inspections excluded. TW =test weight; MC =moisture content; HT = heat damage; DKT = total damage; BCFM = broken corn and foreign material; FM = foreign material.

[a](FM/BCFM) × 100.

Figure 3. Effects of particle size on protein and fiber contents in 1977 Illinois corn.



Source: Figures 4 and 5, Hill, 1982.

particle size of screenings were reduced. For all other characteristics, most respondents predicted that the change would cause the average values to decrease.

Based on previous research, a reduction in particle size would increase fiber content and protein content, but would decrease energy levels (Figure 3). The net effect on feed value depends on relative prices of energy and protein. Under current price relationships, the feeding value would decrease. The lack of agreement among responses indicates the lack of sophistication in the corn screenings market and reflects the large number of users without sufficient knowledge, technology, or experience to price screenings according to value. Protein content provides an example. Over 40 percent of the respondents expected protein to decrease with decreased particle size. This is the opposite of the conclusion based on the analysis of screenings. Since few buyers of screenings conduct a detailed analysis of the screenings, buyers had no basis for predicting the effect of changes in particle size. It is not surprising that individual opinions differed from actual analysis.

Value of Fines and Screenings

Nutritive Value in Feed Rations

Hill et al. [1982] measured the nutritive value of various particle sizes of corn fines and whole corn screened from the 1976 and 1977 crops in Illinois. Martin [1981] studied dust from four Kansas elevators. Their results are shown in Table 9.

Protein content increased with decreasing particle size. For fines passing through the 4.5/64-inch sieve, protein content (12.3 percent) was more than two percentage points higher than for whole corn. This suggests that this smallest-size fraction contains a large portion of high-protein germ. The smallest fraction (through a 4.5/64-inch sieve) has by far the highest ash content (4.6 percent), suggesting that a high level of dust and inert material exists in this fraction.

Al-Yahya [1991] determined the nutrient value of corn liftings (material removed by a Kice 6DT4 mini-aspirator) using corn containing 4.0 percent BCFM. Figure 4 shows the effect of air velocity (and particle size) on protein, oil, and starch of the liftings. The starch level of liftings was maximized at a low-velocity setting; the oil level was maximized at a high-velocity setting. The protein level was the least defined, with no evident trend of variation with air velocity. Apparently, high-starch particles have lower terminal velocities, and high-oil particles have higher terminal velocities.

The procedures used by FGIS since 1989 separate BCFM into CFM, BC, and fines with essentially a 100 percent efficiency using the Carter-Day Dockage Tester and handpicking CFM. Substituting an 8/64-inch sieve for the 6/64-inch sieve shows an increase in protein and fiber as particle size decreased, randomly selected from the FGIS file samples from port elevators in 1991. Protein and oil contents were higher and starch content was lower in the FM obtained with the 6/64-inch sieve than with the 8/64-inch sieve (Table 10).

Although commercial cleaners are much less effective in separating particle sizes, the relation-ship between screen size and chemical composition still holds. A port elevator with cleaners using an 8/64-inch screen and

Table 9. Nutritive Properties of Corn Fines

Property	Whole corn (>15/64-in.)	6.0 mm[b] (15/64-in.)	4.8 mm[b] (12/64-in.)	4.0 mm[b] (10/64-in.)	3.2 mm[b] (8/64-in.)	2.4 mm[b] (6/64-in.)	1.8 mm[b] (4/64-in.)	Dust
Crude protein (%)[a]	10.20	10.10	10.40	10.40	10.40	11.00	12.30	9.00
Ash (%)[a]	1.40	1.40	1.60	1.60	1.70	2.40	4.60	6.60
Oil (%)[a]	4.50	3.90	4.30	3.40	2.50	2.40	2.40	2.70
Crude fiber (%)[a]	2.20	2.30	2.60	2.90	3.50	4.20	5.90	8.10
NFE (%)[a,c]	81.8	82.30	81.10	81.70	81.90	80.10	74.70	73.60
Digestible energy[d]								
MJ/kg	16.45	—	15.81	15.57	15.30	15.03	14.84	—
Kcal/lb	1,786	—	1,717	1,691	1,661	1,632	1,611	—

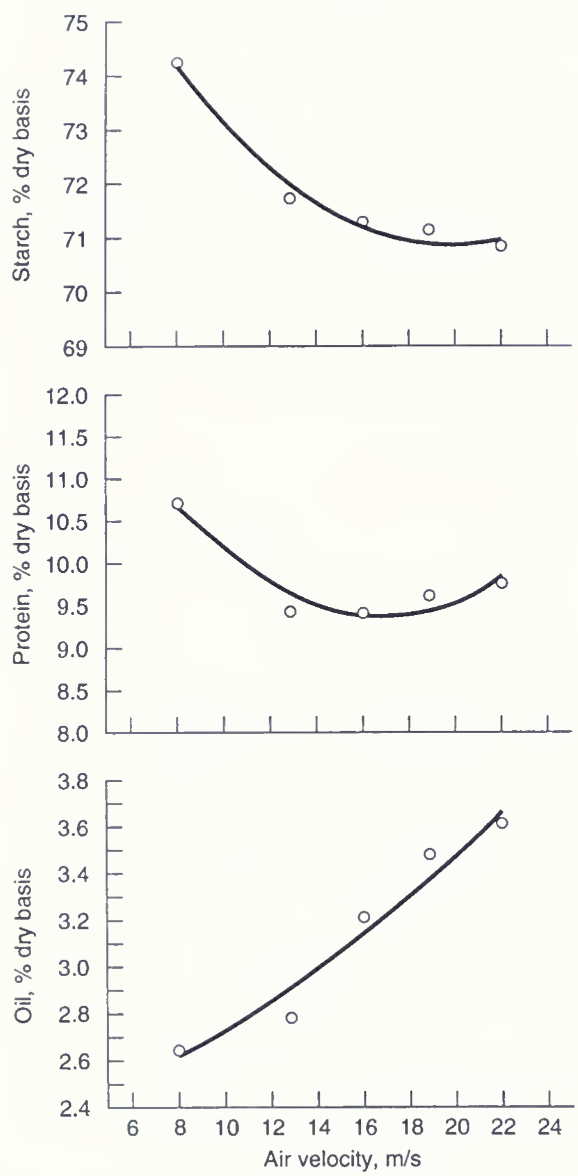
Source: Hill [1982] and Martin [1981].

— = Not available. [a]All percentages are on a dry basis. [b]Size of particles in each category lies between that screen size and the next smaller one. [c]Nitrogen-free extract. NFE = 100 – protein – oil – ash – fiber. [d]Digestible energy = gross energy (calorimeter) – fecal loss.

a 12/64-inch screen split a barge load of corn, running a portion over each cleaner. Random samples of the screenings from the two cleaners were analyzed for particle size and chemical composition. The results show that screenings still contain some particles larger than 8/64-inch in size and cleaned corn still contains fine materials smaller than 8/64-inch. The separation of this particular barge of corn resulted in 0.2 percent FM in the clean corn and as much as 60 percent of the screenings consisting of material larger than 6/64-inch. The use of the 8/64-inch screen in the cleaner, in place of the 12/64-inch screen increased the percent of fines and decreased the percent of coarse broken corn in the screenings as a result of a better separation. There was little change in the composition of the cleaned corn. The chemical analysis of the screenings from the 8/64-inch screen showed a higher protein, higher oil, and lower starch than the screenings from the cleaner using a 12/64-inch screen (Table 11). The differences in starch and protein contents were statistically significant at $p = 0.05$ [Hill et al., 1991c].

Screenings are generally thought to contain a greater incidence of aflatoxin than whole corn. However, in the analysis of samples of screenings collected at Iowa elevators, only one sample out of 62 contained measurable levels of

Figure 4. *Starch, protein, and oil of liftings as a function of air velocity.*



Source: Al-Yahya, 1991.

Table 10. *Effect of Particle Size on Chemical Composition of Foreign Material in Corn*

	- - -*Sieve size (%)*[a] - - -	
Component	6/64-in.	8/64-in.
Protein	9.1	9.0
Oil	3.2*	3.0*
Starch	59.2	59.4

[a]Random samples from FGIS export file samples were separated with the Carter-Day Dockage Tester using a 6/64-inch sieve for 57 samples and an 8/64-inch sieve for 51 samples. The material passing through the sieve was analyzed by near-infrared reflectance technology calibrated for analysis of screenings. Analyses are calculated on a 15 percent moisture basis.

*Statistically different at $p = 0.05$.

Table 11. *Chemical Composition of Screenings Obtained from Commercial Cleaners Fitted with Two Screen Sizes*

	- - - *Sieve size (%)* - - -	
Component[a]	12/64-in.	8/64-in.
Protein	9.6*	10.4*
Oil	3.1	3.3
Starch	57.9*	56.8*

[a]Calculated at 15.5 percent moisture.

*Statistically different at $p = 0.05$.

aflatoxin. Shotwell et al. [1972] found that aflatoxin was present in both BCFM and whole kernel portions of contaminated samples. In the study, two of 13 contaminated samples examined contained high concentrations of aflatoxin B_1 in the BCFM portion of the samples. Hill et al. [1982] also reported a low correlation between particle size and aflatoxin levels. The results of these three studies suggest that removal of BCFM or corn screenings will not eliminate the problem of aflatoxins.

Most samples of screenings from country elevators analyzed in this study contained fumonisin in one or more fractions. There was a generally declining trend of fumonisin levels as particle size increased. This means that smaller fines, if removed as a separate product, would represent a greater risk of fumonisin than current screenings derived under the current definition of BCFM. The weighted average fumonisin content of the 62 samples analyzed in this study was 30 ppm. In general, all forms of fumonisin toxins follow the same pattern.

Characteristics of Screenings That Affect Value

The value of screenings is influenced by their physical and chemical attributes. When the quantity of screenings is increased by removing more BCFM from the corn, the majority of the net addition will be broken corn, while the quantity of CFM in the screenings remains constant. Increased cleaning will therefore improve the quality of screenings through lower fiber and higher test weight. Test weight was the primary factor that elevator survey respondents thought would influence value. Buyers of corn screenings were asked to rate the importance of moisture, test weight, protein content, fiber content, and particle size in determining the value of the corn screenings that they used. Respondents rated the characteristics on a scale of 1 to 3, where 1 indicated little or no importance, 2 signified some importance, and 3 indicated very important.

Over 66 percent of the respondents rated moisture and test weight "very important" (Table 12). Protein content and particle size were secondary considerations, while fiber content appeared to be of minor importance to most users. Only 3.9 percent of the respondents rated fiber as very important. Respondents were also given the opportunity to list any other characteristics that they thought would influence the value of screenings. Odor, cool and sweet, ash, and presence of aflatoxin were listed by 15 percent or fewer of the respondents. Respondents did not rate these factors as to relative importance.

Characteristics of Screenings That Affect Price

The value of screenings may not be reflected in price, so buyers were asked which of five characteristics were important in determining the market price for corn screenings. The alternatives presented in the survey were the same as those used in determining value:

Table 12. Determinants of Value in the Corn Screenings Market

	Ratings by respondents (%)[a]		
Factor	1 (Little or no importance)	2 (Some importance)	3 (Very important)
Moisture	0.0	23.1	66.7
Test weight	0.0	15.4	74.1
Protein content	34.6	38.5	25.9
Particle size	29.6	42.3	26.9
Fiber content	51.9	38.5	3.9

[a]Percentages do not add to 100 because some respondents did not rate all factors.

moisture, test weight, protein content, fiber content, and particle size. Instead of rating these characteristics, however, respondents were asked to indicate all that applied (Figure 5).

Over 90 percent of all respondents reported that test weight affects the price of corn screenings, while over 50 percent listed moisture (Table 13). Protein content, particle size, and fiber content were relatively minor considerations. Buyers again were given the opportunity to list other factors that affected price, and they responded with answers of musty or moldy screenings, ash content, and aflatoxin. It is of interest that while ash content was listed as affecting price, it was not rated as important to value. Although 11.5 percent of the respondents said fiber content affects price, only 3.9 percent gave it a score of very important.

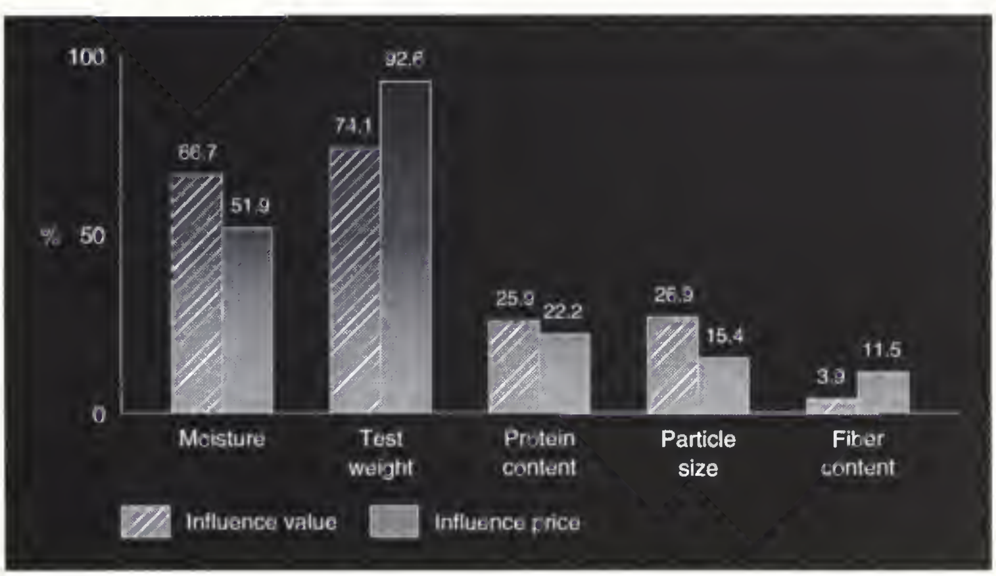
The survey identified moisture and test weight as two of the most important characteristics that influence price (or discounts) for corn screenings. Test weight is a general indicator of the composition of the screenings—low test weight screenings will often have less grain, smaller particles, and more plant by-products, such as cobs and chaff. However, the actual value as a feed ingredient is a function of the energy, protein, and fiber contents. Particle size also has an effect on palatability, and thus feeding value, if screenings are fed directly. Over one-quarter of the respondents recognized the importance of protein content and particle size in determining value. However, only 15.4 percent said particle size was a consideration in setting prices.

Separating BCFM by using a double sieve (12/64-inch and 6/64-inch) will significantly reduce particle size and increase fiber content in the material defined as FM. It will also have a small effect on the protein content. The BC portion of the sample will contain less fiber and protein and more starch and energy than the current BCFM, although the differences will be small since most of the BCFM under current grades is comprised of BC.

Table 13. Quality Characteristics That Affect Price in the Corn Screenings Market

Factor	% of respondents identifying the characteristic
Test weight	92.6
Moisture	51.9
Protein content	22.2
Particle size	15.4
Fiber content	11.5

Figure 5. Percent of respondents rating influence of quality characteristics on value and price of corn screenings.

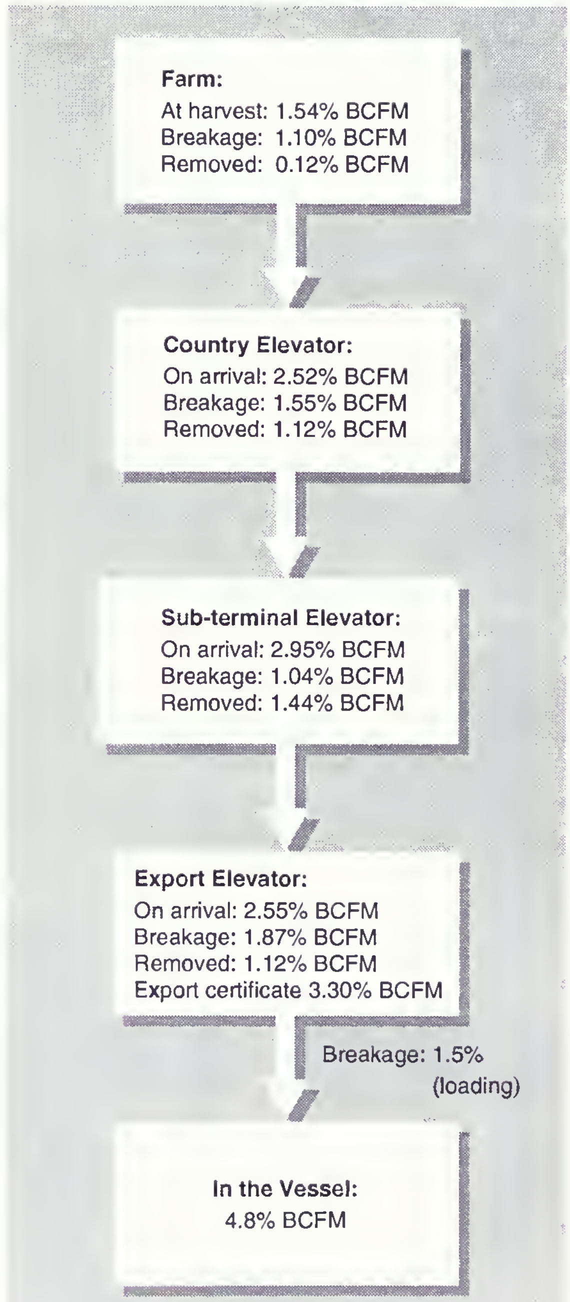


Costs and Benefits of Cleaning

Costs associated with varying levels of BCFM in market corn are difficult to assess because they vary with intended use, storage practices, location in the market channel, and other environmental and market conditions. Corn screenings included in whole corn increase costs of handling and storing corn and reduce its value. They make the corn more difficult to aerate [Grama et al., 1984]. They increase the rate of spoilage [Kalbasi-Ashtari et al., 1979]. They segregate from whole kernels under a filling spout [Stephens and Foster, 1976]. The presence of fines is the grain quality problem most commonly mentioned by grain elevator and storage facility managers [Stroshine, 1992]. They are the most likely cause of a drop in grade during shipment [Hill et al., 1979]. They add to processing costs because they are usually removed prior to wet milling [May, 1987] and dry milling [Alexander, 1987]. Fines existing as dust (solid particles that became airborne) constitute fire, explosion, and health hazards [Martin, 1981].

Breakage during transport and handling of corn in the market channel often creates additional BCFM, resulting in levels that exceed the limit for grade No. 2 in domestic markets or grade No. 3 in export markets (Figure 6). Meeting these contract grades requires cleaning, and cleaning generates corn screenings. The additional costs of receiving corn with BCFM levels above grade limits are operation of grain cleaners, transportation of screenings to the point of use (primarily livestock feed), storage of screenings, and a reduction in total weight sold. Inefficiency in the system has often been illustrated by the example of corn being shipped at 3 percent BCFM by a subterminal elevator in the Midwest, incurring transportation costs between production areas and the port elevator. At the port elevator, where handling increases BCFM above the No. 3 grade limit (4 percent), the excess screenings must be removed and may be shipped back to the

Figure 6. Changes in BCFM through the market channel.



Breakage includes that occurring in the firm and during transportation to the next marketing point.

elevator that shipped the original 3 percent BCFM. Shippers pay additional transport costs for the return trip. While this may be an unusual example, it does occur and illustrates one of the issues demanding an analysis of alternative systems. Lower levels of BCFM in the market channel can reduce costs of transport and storage. But cost **savings** through reducing levels of BCFM must be balanced against the costs **created** in removing excess BCFM. Costs and benefits are determined in part by the characteristics of the screenings generated during cleaning. The value of corn and screenings, the costs of aeration, and the quality of corn are affected by the properties of the material removed.

Costs of Cleaning

Reducing the level of BCFM in corn entails a cost, whether done by combine adjustments, weed control, or cleaning. Table 14 summarizes the variables involved in determining the costs of cleaning.

Cleaner Operating Costs

Operating the cleaner is one of the more obvious costs incurred during cleaning. The cost of owning and operating a grain cleaner varies with size and type of cleaner, volume cleaned, target level for BCFM, and location in the market channel (farm versus country elevator versus export elevator). Information about cleaning practices and costs was obtained through national surveys of farm and elevator managers. The survey of farmers showed average cleaning costs of 2.7 cents per bushel per point. Average costs of cleaning at the country elevator were 3.2 cents per bushel.

Even though the survey responses did not specify the levels of other variables that could influence cleaning costs, these estimates are close to the costs calculated from the economic-engineering approach reported later in this study (Table 15). Reported costs on the farm were lower than the calculated costs, but farmers often consider only out-of-pocket costs when responding to surveys. The engineering cost study at farm and elevator was also based on the purchase of new equipment. Many farms and elevators already have cleaners and cleaning capacity. Additional cleaning could be accomplished at variable cost up to the maximum capacity achieved through more hours of operation. The number, type, and capacity of grain cleaners at each point in the market channel are shown in Table 16. In order to aggregate costs it is necessary to calculate all values on the basis of bushels of corn cleaned.

In the economic-engineering model, the purchase and operation of the cleaner, C_1, was calculated in dollars per bushel of corn cleaned. Capital costs are based on compound-interest amortization of initial cost (installed). Tax savings for cash expenses are included because this will decrease some costs but not others. Furthermore, some benefits will generate cash revenues, which are taxable, while others will not. The formula for calculating the cost of operating a cleaner includes the following variables: purchase price, tax credits, capital recovery factor as a function of years of life and interest rate, percent of purchase price for annual repairs, insurance premium, annual cash payment for interest, useful life (years), annual depreciation deduction, annual labor charge, annual energy cost (dollars per KWH), bushels cleaned per year, income tax rate (decimal), and volume cleaned (bushels) [Meinders and Hurburgh, 1992]. Most of these require case-by-case assumptions. Annual energy cost is based on hourly throughput, bushels cleaned per year, the hourly power consumption, and electricity cost.

Weight Loss

Loss in weight of screenings removed, C_2, was calculated in the economic-engineering model in dollars per bushel of corn cleaned.

The screenings removed during cleaning represent weight that could have been delivered and sold at the price of corn as grain. Discounts avoided (if any) and feed value of cleanings are counted as benefits.

$$C_2 = \frac{W_s}{56} P_c \qquad (4)$$

where

C_2 = loss in weight of screenings removed
W_s = weight of screenings generated per bushel of corn cleaned
P_c = corn price in dollars per bushel

Reducing the level of BCFM in corn by 1 percentage point requires removal of more than

Table 14. Cost–Benefit Model Variables, Farm Cleaning Case Studies

Item	Rotary cleaner	Gravity cleaner
Cleaner cost, installed ($)	5,280	3,700
Tax credit ($)	0	0
Interest rate (%)	10.0	10.0
Useful life (years)	10	10
Repair percentage	5	5
Insurance premium ($/$1,000)	10	10
Depreciation allowance (%)	10	10
Annual interest payment ($)	0	0
Annual incremental labor ($/year)	0	0
Per-hour energy cost ($)	0.26	0
Throughput (bu/hour)	2,500	3,000
Bushels cleaned per year	50,000	50,000
Income tax rate (%)	30	30
Property tax rate ($/$1,000)	20	20
Cleaning efficiency (all sizes 16 and below, fraction of cleaning efficiency for BCFM)	0.75	0.40
Cleaning efficiency for BCFM (%)	43	50
Percent BCFM	1.5	1.5
Months screenings are stored	1.0	1.0
Value of storage ($/month)	0.02	0.02
Cost of elevation ($/bu)	0.005	0.005
Transportation—corn ($/bu)	0.05	0.05
Test weight—corn (lb/bu)	56	56
Test weight—screenings (lb/bu)	40	40
Screenings shipped (%)	0	0
Screenings value (% of corn price, $)	0.80	0.80
Cost of new test ($)	0	0
BCFM allowed without discount (%)	3.0	3.0
Discount rate (% of price per point above 3.0%)	1.0	1.0
Inbound discount ($)	0.00	0.00
BCFM increase after cleaning (%)	0.5	0.5
Months corn is stored	6	6
Aeration management factor	1.5	1.5
Cost of electricity ($/kwh)	0.07	0.07
Fan output elasticity	0.8	0.8
Airflow per watt—uncleaned (CFM/W)	0.8	0.8
Months of storage—fall, spring	3, 3	3, 3
Discount rate for new factor(s) (%)	0.0	0.0
Average value of new factor ($)	0.0	0.0
Limit for new factor (%)	0.0	0.0
Corn price ($/bu)	2.50	2.50

1 percent of original weight. The formulas for calculation are

$$(100 - B_b)W_b = (100 - B_a)W_a \qquad (5)$$

and

$$W_s = \frac{W_b - W_a}{W_b} \qquad (6)$$

where

B_b = percent BCFM before cleaning
W_b = total pounds, tons, or bushels of clean corn plus BCFM before cleaning
B_a = BCFM after cleaning
W_a = total pounds, tons, or bushels of clean corn plus BCFM after cleaning
W_S = weight of screenings generated per bushel of corn cleaned

Transposing equation (5) gives

$$W_a = \frac{(100 - B_b)}{(100 - B_a)} (W_b) \qquad (7)$$

The amount of screenings removed to achieve 1 percentage point reduction will vary with the value of B_b as well as B_a, but it will

Table 15. Cost and Benefits for Two On-Farm Corn-Cleaning Examples

	Rotary cleaner ($/bu)	*Gravity cleaner* ($/bu)
Costs		
Fixed cost of cleaner	0.020	0.014
Variable costs of cleaner	0.001	0.000
Weight loss	0.032	0.022
Screenings storage	0.001	0.000
Transportation of screenings	0.000	0.000
Increased testing	0.000	0.000
Total costs	**0.054**	**0.036**
Benefits		
Screenings value	0.026	0.017
Reduced freight	0.002	0.000
Shrink savings	0.004	0.004
Spoilage savings	0.003	0.003
Less handling	0.000	0.000
Discount avoided	0.000	0.000
Aeration savings	0.011	0.013
Moisture shrink	0.004	0.008
New discount	0.000	0.000
Total benefits	**0.050**	**0.046**
Net (benefits minus costs)	**–0.004**	**0.010**

Table 16. Number, Size, and Type of Grain Cleaners at Farms and Elevators

	No. of cleaners	% owning cleaners	Average capacity of cleaner (bu/hr)[a]
Farm	149	39.8	1,400
Interior elevator			
Country	427	50.4	3,300
River	36	42.9	11,900
Sub-terminal	18	69.2	4,600
Export elevator	86	100.0	22,700

Sources: Unpublished national surveys conducted by the University of Illinois.

[a]Rounded to the nearest 100 bushels.

always exceed 1 percent unless B_b equals 0. The mathematical relationship among percentages and weight loss is the same for BCFM as for moisture.

The mathematical procedures for calculating an estimate of W_s based on cleaning efficiency, type of cleaner, size of screen, and bushels of corn cleaned are illustrated in Meinders and Hurburgh [1992].

Transportation Costs

Increased cleaning will increase the quantity of screenings on the market. If this increase occurs in areas distant from the point of consumption (for example, at the export elevator), significant transportation costs will be incurred.

Under some circumstances there is a trade-off between transporting a larger quantity of corn and transporting a larger quantity of screenings, since both may be used in feed formulation. The transportation rate for transporting screenings is usually higher than that for corn, primarily because of the greater bulk space required for a ton of screenings.

The distance transported varies by geographical region, by use, and with seasonal changes in supply and demand. The percent of screenings removed was based on survey data. Transport rates will be higher than for corn and can be estimated in either of two ways. The first is based on the assumption that transport rates are a direct function of volume per unit of weight. Screenings are less dense than corn. Test weights of corn and screenings provide an adjustment factor to apply to corn transport rates.

$$T_s = \frac{tw_c}{tw_s} T_c \qquad (8)$$

where

T_s = transportation rates for screenings (dollars per ton per mile)

tw_c = test weight of corn (pounds per bushel)

tw_s = test weight of screenings (pounds per bushel)

T_c = transportation rates for corn (dollars per ton per mile)

In most transactions, transport rates for screenings are not calculated as a percentage of rates for corn. An alternative method for calculating costs for transporting screenings uses quoted commercial rates for screenings. Total transportation cost is also a function of rate times distance. Since many farmers and elevators use screenings as feed on the premises, transportation rates and distance as a cost factor should be used only for screenings entering the market channel. Hill et al. [1991e] found that about 65 percent of screenings removed at interior commercial elevators was processed on-site into mixed feeds. The remaining screenings were shipped to other locations, incurring a cost of transport. The percent of screenings entering the market is a unique number for each firm. Rates (T_s), distance transported (D_s), and percent entering the market (M_s) are incorporated into the second equation for calculating costs of transporting screenings in cents per bushel of corn cleaned.

$$C_3 = T_s W_s M_s D_s \qquad (9)$$

where

C_3 = cost of transporting screenings dollars per bushel of corn cleaned

T_s = transport rate for screenings in cents per pound per mile

W_s = pounds of screenings generated per bushel of corn cleaned

M_s = percent of screenings entering the market channel

D_s = average distance transported (miles)

Testing and Measurement

Changes in grading practices will require a change in costs, both at the country elevator and in the official grading and inspection agencies. While the increased cost for one inspection procedure can be estimated, the number of inspections and analyses performed by elevator or FGIS employees will depend upon industry response to the opportunity for obtaining the new information. If, in the process of adapting to a new set of grades, an elevator finds that it must test grain for one or more characteristics not presently measured, then the cost of the new tests should be assessed against the requirement (or opportunity) for increased cleaning. FGIS–USDA has developed a table of standard times for sample analysis and grade determination for performing the various activities associated with quality determination (Table 17). The times required for each test cover a wide range and differ markedly from sample to sample. Hand operations, such as picking damage or CFM, require more time than mechanical operations.

Additional research is needed to determine the times required for conducting other types of analyses, such as using two sieves for determining BC and FM as separate factors. The CFM handpick, at 6.8 minutes per sample, costs about $2.25 per sample (about $0.005 per bushel if the sample represents 500 bushels and the wage rate is $20 per hour). Cost per bushel of corn cleaned for this factor is the additional cost per bushel of corn inspected. Similar estimates are required for any additional sampling and grading required as a result of changing grades to include separate measurement of BC, FM, or CFM.

Testing costs can be modeled with a complete economic analysis using time and motion studies for each factor or can be an estimated constant. The latter approach is used here, recognizing that each test and analytical operation will have a different cost factor.

Table 17. Standard Times for Grading Corn Samples

Description	Minutes
Sample ticket preparation	0.47
Boerner divider	2.56
Prepare file sample	0.30
Temperature and moisture meter	2.46
Test weight per bushel	0.75
Total damage	16.70
Carter-Day Dockage Tester	1.90
Handpick Coarse Foreign Material	6.80
Travel between equipment	0.55
Total standard minutes	**32.49**

Source: Items were selected from Tables 54 and 60 of Federal Grain Inspection Service, 1980. Times varied widely depending on quality of the corn as well as operating conditions.

$$C_4 = \sum_{i=1}^{n}, I_i$$

where

C_4 = dollars per bushel of corn cleaned

I_i = inspection cost for measurement i

Storage Costs

Screenings removed from corn that are not sold or fed immediately will require storage. Seasonal changes in supply and demand also provide incentives for storing screenings. Since screenings are less dense than corn, they will occupy more storage volume per unit of weight than will clean corn or the same weight of screenings mixed with corn. Assuming the same pack factor of corn and screenings, relative storage volume will be inversely proportional to test weight. Storage space is worth money to elevators, so an increased volume of screenings removed will utilize more short-term storage and reduce the storage space available for corn. Interior elevators and export elevators reported storing screenings for 1 to 3 months [Hill et al., 1991b, 1991d]; users of screenings reported an average storage time of 10 days [Hill et al., 1991e].

The calculation of storage and handling cost, C_5, per bushel of corn cleaned is

$$C_5 = (n_s C_{st} + C_h) \frac{tw_c}{tw_s} W_s \qquad (10)$$

where

n_s = number of months screenings are stored

C_{st} = cost of storage for corn in dollars per bushel per month)

C_h = cost of handling in dollars per bushel

tw_c = test weight of corn in pounds per bushel

tw_s = test weight of screenings in pounds per bushel

W_s = weight of screenings generated per bushel of corn cleaned

Benefits of Cleaning

Mechanical removal of BCFM generates several economic benefits related to cleaner corn and the value of screenings.

Discounts Avoided

The market incentive for cleaning is reflected in the discount. Any corn with BCFM above the base level receives a discount in the form of reduced price or reduced weight. This is the reason most frequently given by interior elevator managers for cleaning [Hill et al., 1991d]. Discounts vary among elevators, geographical areas, and over time. Elevators in Iowa reported typical discounts of 2 cents per bushel for each percentage point above 3. The most prevalent discount reported by Illinois elevators was 1 cent, although 2 cents was not uncommon [Bekric and Hill, 1991]. For purposes of illustration, a 2-cent discount will be assumed.

If BCFM were separated into a BC factor and an FM factor, the discounts would probably change. One proposal has been to subtract 0.1 percent of the gross weight for each 0.1 percent of FM starting at zero [North American Export Grain Association, 1986]. Since BCFM consists primarily of BC, a discount of 2 cents per bushel per percentage point above grade limit will also be used for BC. However, given the distribution of BC and FM, the grade limit for BC was assumed to be 2.5 percent. Assuming a corn price of $2.25 per bushel, 3.2 percent BC, and 0.8 percent FM (4.0 percent BCFM), the discount under current grades can be compared to the discounts under the revised grade limits and factor definitions.

Under current grades the total reduction in value would be 2 cents per bushel (4.0 percent minus 3.0 percent times $0.02 = 2 cents). Under the proposed two-factor grades, the 4.0 percent BCFM on average is distributed as BC = 3.2 and FM = 0.8.Using a weight deduction of 0.1 percent for each tenth percentage point of FM above zero and a discount of 2.0 cents per bushel for each percentage point of BC above 2.5 percent, the reduction in value is 3.2 cents per bushel, or 1.2 cents more than current discounts. These discounts converge at high BCFM levels.

$2.25 × 0.8 × .01 =	$0.018	=	1.8 cents per bushel
$0.02 × 0.7 (3.2 – 2.5) =	$0.014	=	1.4 cents per bushel
Reduced value =	$0.032	=	3.2 cents per bushel

The reduction in value under the current system relative to the proposed system varies with the price of corn when the BC to FM ratio is held constant, but discounts under the proposed system are higher than under the current system. In this example, at costs of cleaning above 3 cents per bushel, market discounts under the current system do not provide an incentive for cleaning until BCFM exceeds 4.5 percent. Under the alternative system, BC plus FM must exceed 4 percent (BC = 3.2; FM = 0.8) before the reduction in discounts would exceed cleaning costs (Figure 7). Other benefits from clean grain, such as reduced costs of transportation, aeration, and handling losses, would lower the break-even point.

The economic-engineering model included the following equation to calculate discounts avoided, β_1, in dollars per bushel of corn cleaned:

$$\beta_1 = (B_a - B_{max})\ d \qquad (11)$$

where

B_a = actual BCFM level (percent) prior to shipping

B_{max} = BCFM limit (percent)

d = discount rate in dollars per bushel for each percent over B_{max}

The discount rate (d) can also be specified as a percent of the price of corn. The benefit calculation only applies if B is greater than B_{max}.

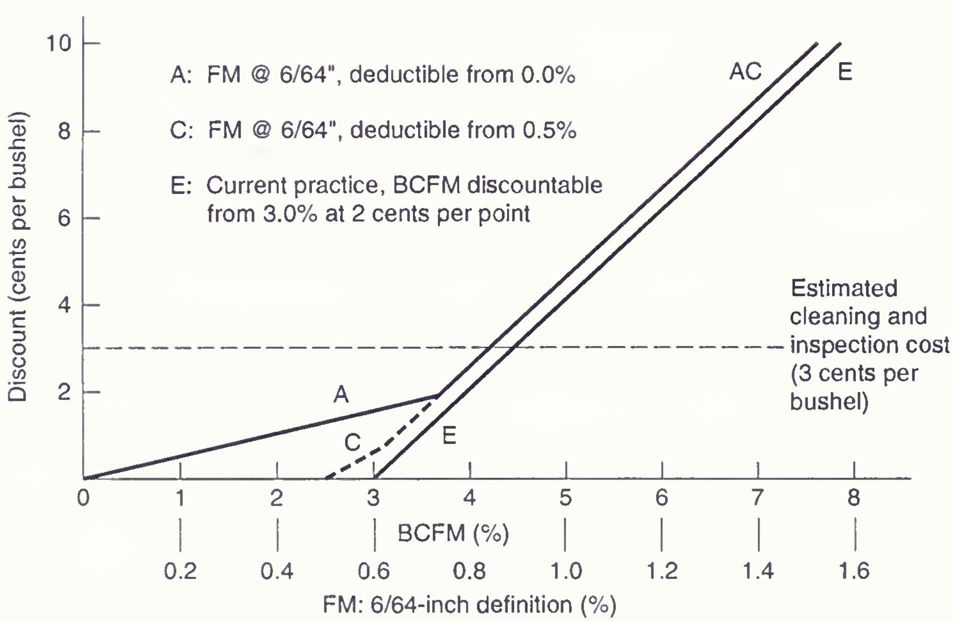
Revenue from the Sale or Use of Screenings

For immediate feed use, the value of screenings is very close to that of whole corn. Although screenings have lower total digestible nutrient values and higher fiber, this decrease in value is offset by a higher level of protein. The value of screenings sold varies with the price of screenings. The average price at interior elevators in 1989 was $81.20 per ton, about 87 percent of the average price of corn at country elevators in 1989. The total screenings volume in the market (interior plus export elevators) was estimated to be 2,118.9 thousand tons [Hill et al., 1991e]. Increased cleaning will generate additional quantities in the market; a greater quantity will result in lower prices.

Interior elevators reported cleaning 48.2 percent of the corn received and 49.5 percent of corn shipped in 1989. On average, they reduced BCFM by 2.15 percentage points in the corn that they cleaned. If the BCFM grade limit for No. 2 corn was lowered from 3 percent to 2 percent, it would be necessary for elevators to clean an additional quantity of receipts and shipments in order to ship No. 2 corn, removing an average of 1 percentage point more BCFM on the corn already being cleaned. Expanding the survey results to represent all corn handled by all elevators gives an estimated volume through interior elevators in 1989 of 6.0 billion bushels (this includes handling the same grain more than once as it moves through the market channel).

Under a grade limit, below the current limit of 3.0 percent, 50 percent of this volume will be cleaned to remove 3.15 percentage points of BCFM instead of 2.15. Assuming that another 25 percent not previously cleaned requires removal of 1 percentage point, the estimated volume of screenings generated would be 3.9 million tons—1.9 million above 1989 volume. If the price of screenings is approximately 75 percent of the price of corn, the transfer of 1.9 million tons of "corn" into "screenings" through additional cleaning to meet lower BCFM limits could represent a loss of $35 to $40 million. However, a change of that magnitude would also affect the price of corn, feed rations, and other economic variables. Based on elasticities calculated from the elevator surveys, every additional 100,000 tons of screenings entering the market reduced the average price of screenings by $14.00 per ton. Based only on the

Figure 7. Discount for corn with increasing FM and BCFM.



calculated elasticity, the price of screenings would drop to zero under a scenario where the volume of screenings increased by 1.9 million tons over the 1989 volume. However, elasticity estimates are valid only for small, incremental changes in quantities. A 100 percent increase in the volume of screenings is clearly beyond the range over which the elasticity could be assumed to hold. Additional information must be used in estimating the price effects.

Since corn and screenings are partial substitutes in many feed rations, the true feeding value would temper the price reduction. As the price of screenings falls, screenings would replace a larger and larger volume of corn. High-BCFM corn or pure screenings would be used for feed, with the ratio between corn and screenings prices reflecting relative value. The nutritive value of screenings vis-à-vis corn, minus handling and processing costs, would put a floor below which screenings prices would not fall. Analysis of screenings composition and value in livestock rations suggests that the price of screenings would not fall below 60 percent of the price of corn. As the quantity of screenings increases by 1 ton (through cleaning), the quantity (weight) of corn in the market channel would decline by 1 ton, primarily in the more quality-conscious export market. Price and quantity of corn and screenings would both change, but there is no model that can accurately predict a new equilibrium. Cleaner corn results in higher yields of processed products, increasing the value. In competitive markets, price will follow value subject to the additional influence of supply and demand. The nutritive value of screenings of various particle sizes also provides a rough approximation of economic value, which will be translated into prices.

The economic-engineering model equation to calculate revenue from the sale or use of screenings, β_2, in dollars per bushel of corn cleaned is

$$\beta_2 = P_s W_s \qquad (12)$$

where

P_s = price of screenings in dollars per pound
W_s = pounds of screenings removed per bushel of corn cleaned

Reduced Freight Expense for Corn

When additional BCFM is removed from corn, a smaller volume of corn remains. Some markets will require the same volume and will replace screenings removed with additional clean corn. Other buyers may be satisfied with a smaller quantity of cleaner corn that will generate the same quantity of processed products. Since there is a fixed quantity of total production within a crop year, there will be more screenings and less corn requiring transport. If the rate in cents per bushel per mile for shipping corn is T_c, then the economic-engineering equation for reduced freight expense for corn, β_3, in dollars per bushel of corn cleaned is

$$\beta_3 = \frac{W_s}{56} T_c D_c \qquad (13)$$

where

W_s = pounds of screenings removed per bushel of corn cleaned
T_c = transport rate for corn in dollars per bushel per mile
D_c = average distance cleaned corn will be transported

Reduced Physical Shrink

Cleaning removes fine material, including dust, some of which would ordinarily be lost in handling. Bern and Hurburgh [1992] reported an average of 0.1 to 0.2 percent dust loss in grain handlings. This is consistent with opinions of handlers. Retention of this material as screenings reduces shrinkage losses according to this equation:

$$\beta_4 = 0.002\ P_s \qquad (14)$$

where

β_4 = reduction of physical shrink in dollars per bushel of corn cleaned
P_s = price of screenings in dollars per pound

Reduced Mold and Insect Shrink

On average, U.S. corn deteriorates from about 2.0 percent total damage at harvest to about

4 to 5 percent at export. An increase of 3 percentage points of damage is accompanied by about 0.5 percent weight loss in dry matter and moisture [Saul and Steele, 1969]. Fines harbor mold and prevent good aeration. It is not unreasonable to assume that this deterioration (which occurs primarily in storage on farms and country elevators) could be halved by cleaning, leaving more saleable weight in bins for each bushel of corn that has been cleaned. The economic-engineering model equation for reduced mold and insect shrink, β_5, in dollars per bushel of corn cleaned is

$$\beta_5 = 0.0025\ P_c\ (0.33B) = .00083\ P_c\ B \qquad (15)$$

where

P_c = price of corn in dollars per bushel
B = percent BCFM

0.33B is used to linearize the savings, centered on 3% BCFM.

Reduced Handling Costs

Grain is often turned to maintain condition. This analysis assumes cleaned corn will require one less turning, saving the handling costs associated with turning for each bushel of corn cleaned. Elevators estimate turning costs at about 1 cent per bushel, including shrinkage losses. The equation to determine reduced handling costs, β_6, in dollars per bushel of corn cleaned is

$$\beta_6 = C_h + C_{sh} \qquad (16)$$

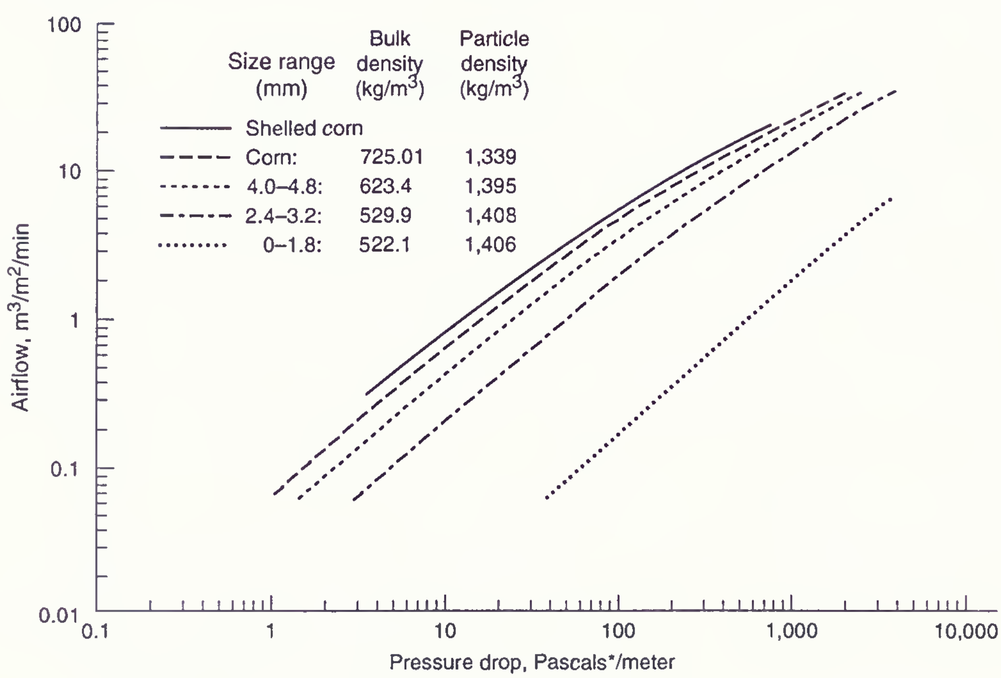
where

C_h = handling cost
C_{sh} = value of shrink during handling

Reduced Aeration Costs

Two factors influence aeration costs in handling corn: airflow resistance and density. Fines

Figure 8. Airflow resistance prediction of clean corn and sized fines.



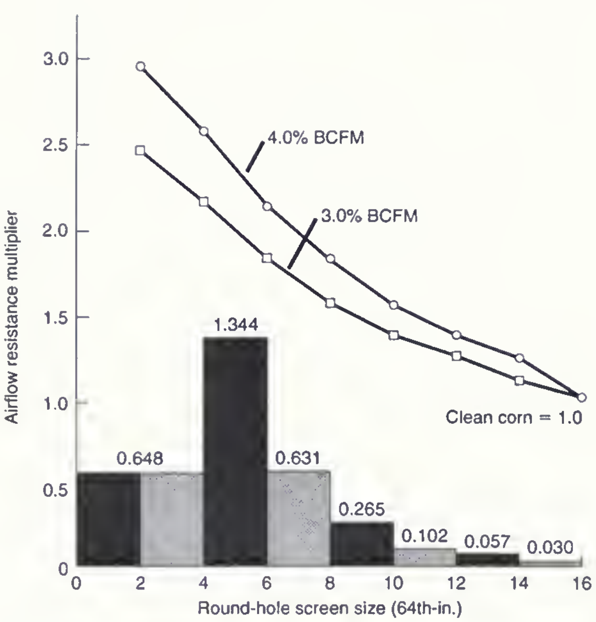
*248.9 Pascals = 1 in. water; 6,894.8 Pascals = 1.0 psi

Sources: Yang et al., 1990; Shedd, 1953 (shelled corn data).

in corn cause a substantial increase in airflow resistance and aeration power requirements, thereby increasing the cost of cleaning. Yang et al. [1990] measured airflow resistance and density of fines removed from corn by sieving. Experimental airflow resistance data show that the pressure drop through the grain mass is a function of air velocity, particle density, and bulk density. Three particle sizes and whole corn are plotted in Figure 8. Airflow resistance of each successively smaller particle size is higher. Size 7 particles (material through a 4.5/64-inch sieve) exhibit an air pressure drop about 40 times that of clean corn.

The major improvement in airflow comes from removing material 8/64-inch and smaller, as shown in Figure 9. This graph shows the multiplier factor from a 1 percent addition of fines, by size of particle. Removal of particles 12/64-inch and smaller will cut airflow resistance in half. Figure 9 assumes 100 percent cleaning efficiency for sizes below the screen size and 0 percent efficiency for sizes above the screen size. In practice this will not occur, as noted, for example, by Hurburgh, Bern, and Brumm [1989]. Lower removal efficiencies for small sizes and some removal of large fines would flatten out the curves, but the differences between BCFM levels would remain.

Figure 9. Incremental airflow resistance multiplier per percent fines (bars) and decrease in airflow resistance multiplier from cleaning at 100 percent efficiency (lines).



The airflow resistance, R, in any aeration situation will be

$$R = R_c \, Y_n \, k \qquad (17)$$

where

R_c = clean corn airflow resistance (any pressure units)

Y_n = clean corn multiplier for fines grade n containing a mixture of particle sizes

k = clean corn multiplier for other conditions

Fan output will be a simultaneous solution of this equation and the fan performance curve (output versus pressure).

Fans are less effective at higher static pressures [Midwest Plan Service, 1980]. Therefore, increased airflow resistance decreases output and increases energy consumption per unit of airflow delivered. Grama et al. [1984] showed that clean corn (corn with all BCFM removed) would reduce fan power needs from 10 percent (for low-airflow, low-pressure aeration) to 200 percent (for high-airflow, high-pressure drying applications). Low-temperature drying, which relies on fan power rather than supplemental heat, benefited most by cleaning.

Hurburgh [1987] applied this analysis to aeration at grain elevators. No. 2 corn with all BCFM removed showed a $0.006 per bushel per year cost savings over No. 2 corn with 3 percent BCFM, based on 2,000 hours annual fan operation time at 0.1 CFM per bushel.

Clean corn has lower airflow resistance [Grama et al., 1984], which means that fans will deliver more airflow at higher energy efficiency. Increased airflow reduces operating time needed for temperature change cycles. Clean corn also has less spout line concentration of fines. Spout lines divert air and cause excessive aeration of the outer grain in order to cool the center. Hall [1985] estimated the concentration of BCFM in spout lines to be 10 times the average level in the bin.

Aeration benefits can be calculated by modeling the difference in energy costs for aerating cleaned versus uncleaned corn. Aeration cost is a function of fan input power and operating time. Reduced aeration cost, β_7, is calculated as the benefit of lower energy required for aerating clean grain in dollars per bushel.

$$\begin{aligned}\beta_7 &= O_u F_u P_e - O_c F_c P_e \\ &= P_e(O_u F_u - O_c F_c) \qquad (18)\end{aligned}$$

where

O_u, O_c = aeration fan operating times in hours for uncleaned and cleaned corn

F_u, F_c = fan input power in kilowatts for uncleaned and cleaned corn

P_e = price of electric power in dollars per kilowatt-hour

The formulas for calculating power and time requirements under varying conditions of airflow, change cycles, spout lines, operator skills, and particle size distribution are given in Meinders and Hurburgh [1992] and Bern and Hurburgh [1992].

The time required to maintain grain temperature and condition through aeration is less for clean grain than for grain with additional fines unevenly distributed throughout the bin. The need for additional aeration of uncleaned grain will result in moisture reduction below 15 percent and subsequent loss of weight. For average north-central U.S. weather conditions, the moisture loss from evaporation, β_8 (in pounds per bushel), is

$$\beta_8 = 0.0050\ R_a F_t \qquad (19)$$

in the fall, and

$$\beta_8 = 0.0075\ R_a F_t \qquad (20)$$

in the spring (Hurburgh, 1987), where

R_a = airflow rate (CFM per bushel)
F_t = hours of fan operation

This loss will continue down to 12 to 13 percent, the approximate equilibrium moisture content for summer storage. Additional variables required for more detailed estimates are given in Meinders and Hurburgh [1992].

Recovery of Discounts Assessed Against the Seller

Discounts assessed against the seller lowers the purchase price of the grain. To the extent that discounts can be recovered operationally (e.g., by blending or cleaning) rather than passed through, there will be a decrease in procurement costs. Recovery of discounts, β_9, in dollars per bushel of corn cleaned is calculated using the following equation:

$$\beta_9 = (B - B_{max})\ d \qquad (21)$$

where

B = BCFM level (percent)
B_{max} = BCFM limit (percent)
d = discount rate in dollars per bushel for each percent over B_{max}

A Worksheet for Calculations

The nine benefits and five costs can be set up in a two-part worksheet format. This format can also be written in a spreadsheet, such as Lotus 1-2-3. The assumptions in the worksheet example apply to a typical country elevator operation, cleaning corn before storage, under the current grades with BCFM as a grade factor. The output comes in two parts—physical

Table 18. Information for Calculating Cleaning Costs and Benefits for a Typical Country Elevator

Item	Variable	Value
Cleaner cost, installed ($)	P	40,000
Tax credit ($)	t_c	0
Interest rate (%)	i	10.0
Useful life (years)	n_l	10
Repair (% of P)	Pr	5.0
Insurance premium ($/$1,000)	Pi	10
Depreciation allowance per year (% of P)	P_D	10
Annual interest payment ($)	I	0
Annual incremental labor ($/year)	L	4,000
Per-hour energy cost ($)	e	0
Cleaner throughput (bu/hour)	T	10,000
Bushels cleaned per year	V	1,000,000
Income tax rate (%)	t_i	30.0
Property tax rate ($/$1,000)	t_p	20
Cleaning efficiency (all sizes 16 and below, fraction of E_B)	C_t	0.50
Cleaning efficiency for BCFM (%)	E_B	40
Percent BCFM	B	3.0
Months screenings are stored	n_s	3.0
Value of storage ($/month)	V_s	0.02
Cost of elevation ($/bu)	C_h	0.005
Transportation—corn ($/bu)	R_c	0.20
Test weight—corn (lb/bu)	T_c	56.0
Test weight—screenings (lb/bu)	T_s	40.0
Screenings shipped (%)	p_t	50
Screenings value (% of corn price)	f	70
Cost of new tests ($)	C_5	0
BCFM allowed without discount (%)	B_{max}	3.0
Discount rate (% of price per poin above 3.0%t)	d_6	1.0
Inbound discount ($)	—	0
BCFM increase after cleaning (%)	ΔB	0.5
Months corn is stored	n	6
Aeration management factor	$f'_2 = f'_2{}'$	1.3
Cost of electricity ($/kwh)	Pe	0.07
Fan output elasticity	$\Sigma_{Q_r P}$	0.8
Airflow per watt—uncleaned (CFM/W)	Q_w	0.8
Months of storage—fall, spring	n_f, n_s	3, 3
Discount rate for new factor(s) ($)	d_9	0
Average value of new factor ($)	Q	0
Limit for new factor (%)	Q_{max}	0
Corn price ($/bu)	P_c	2.50

variables (Table 18) and cost estimates (Table 19).

It is clear that the key to capturing benefits from cleaning is aeration management. The aeration and moisture shrink savings (the largest benefits) are both dependent on reduced fan operation time. The major contributor to shorter operating time is the elimination of spout lines, thereby gaining a more even distribution of air. Increased output of air per kilowatt of energy used by the fan contributes also, but not to the extent of the air distribution factor. The entire analysis presumes that the operator has the skills and detection equipment to know when the cooling fronts have reached the top of a bin.

On the cost side, weight loss dominates. The more BCFM that is removed, the more weight that is lost. Thus, unless aeration management captures benefits, more cleaning will not give net benefits over costs.

For cleaning on the outbound side (no storage), the only benefits that apply are β1, revenue from sale of screenings; β2, reduced transportation costs; β3, reduced shrink; and β6, discounts avoided. In the example scenario, the elevator would have to face discounts of about 4 cents per bushel to cover costs. This would occur at about 5 percent BCFM. Based on this analysis, the benefit from additional cleaning at load-out will seldom exceed costs for BCFM below 5 percent. Discounts provide the major benefit for cleaning in the market channel. Exporters use cleaners more frequently than farmers or interior elevators, because BCFM increases with handling and the cost of off-loading even small amounts of grain over the contract limit is about $1 per bushel, significantly more than the cost of cleaning. Most of the cleaning of corn at export elevators is done in response to absolute limits set by the contract, rather than to avoid discounts.

Table 19. A Sample Income–Expense Statement for Cleaning Corn at a Country Elevator

Equation no.[a]		$/bu
	Costs	
C_{1a}	Fixed cost of cleaner operation	0.008
C_{1b}	Variable cost of cleaner operation	0.003
C_2	Weight loss	0.043
C_3	Storage of screenings	0.001
C_4	Transportation of screenings	0.002
C_5	Increased testing	0.000
	Total costs	**0.056**
	Benefits	
β_1	Sale of cleanings	0.030
β_2	Reduced freight	0.003
β_3	Reduced physical shrink	0.004
β_4	Reduced mold, insect shrink	0.006
β_5	Reduced handling cost	0.000
β_6	Discount avoided	0.013
β_7	Reduced aeration costs	0.012
β_8	Reduced moisture shrink	0.000
β_9	Additional discounts levied	0.000
	Total benefits	**0.068**
	Net (benefits minus costs)	**0.011**

[a]Equations for calculating each cost and benefit are described in the text, identified by the letter–number code.

Limitations of the Micro Approach

Economic evaluation of the nationwide effects of separating BCFM into two factors requires that the cost-to-benefit calculation of Table 19 be aggregated across all farms and all elevators. However, each firm is almost a unique case, with different values for corn quality, aeration strategies, type and age of cleaner, storage times for corn and screenings, transport rate and distance, etc. There are no national averages for these variables, nor any basis even for estimating averages for most of them.

In addition, there are several alternative ways of defining BC and FM and incorporating them into grades and standards. Evaluating the aggregate net benefit of grade changes requires a different approach than a firm-level budgeting model. The firm-level model can only provide comparative insight into the probable direction of response—more cleaning or less cleaning.

Evaluating the Scenarios

Developing the Scenarios

An evaluation of the economic impact of changing grades and standards must be conducted within the framework of the purposes identified by legislation and economic principles. Inherent in the request for economic impact information is the implicit assumption that these changes will somehow alter the distribution of income among individuals or economic sectors of the market channel or will increase the U.S. share of international markets. However, the purposes of grades and standards in the 1986 Grain Quality Improvement Act do not include the redistribution of income between farmers and grain handlers. Better communication, improved quality of information, and increased marketing efficiency can all be deduced from the purposes of grades and standards. Increasing aggregate farm income is not included as an objective of uniform federal grades and standards. Increased income will come from delivering better quality, from providing more valuable services to buyers and final users, and from supplying high-quality corn to new, higher priced markets. Changes in grades or factor definitions combined with price differentials in the market may provide the necessary incentives to change the production and marketing practices that control quality, but grade changes alone will have little effect on prices, profits, or market share unless they are accompanied by changes in the practices of producers and handlers.

U.S. market shares in world trade are influenced by many factors— prices, exchange rates, trade policy, production costs, etc. Quality is not a major determinant in production and export volume of competing exporters, and the connection between grades, quality, and market share has not been quantified as statistically significant. Better quality and customer service have the same effect as lower prices; they discourage expansion of production in other exporting countries. However, short-run effects on market share will be small.

Costs and benefits must, therefore, be evaluated on the criteria of market information, market participant response, and facilitating efficiency in market transactions. Changes in transportation and handling costs, delivered quality, and value of the product are secondary effects that are controlled by the response of market participants: a change in factor definitions or grade limits may be the stimulus that initiates the response.

This principle is especially appropriate in the evaluation of the benefits. The benefits of nationally uniform grades and standards accrue to the market in the aggregate; individual firms may not recognize any direct benefit from changes in their daily operations as a result of FGIS regulations. The primary benefit to the aggregate market is more efficient communication in complex market transactions. This "benefit to all" is often not recognized as a "benefit to me," and individual firms may logically oppose changes that appear to improve aggregate efficiency.[2]

Economic impacts are generated only when marketing firms make decisions that affect prices, ownership, or resource allocation in response to new information or new incentives. Separating BC and FM in corn grades does not directly alter quality, value, or prices of corn. The impact occurs only if and when the grade changes are accompanied by changes in practices of buyers and sellers. If the definitional revision of a grade factor alters the economic incentives as viewed by decision makers, it will influence actions that determine corn quality. If grain handlers ignore the new definition in setting prices and discounts, the impacts will be very minor. Estimating the impact requires aggregating the individual firm responses that were partially modeled in the preceding pages. No empirical data or experimental results are available to make such predictions. The responses of production and marketing firms will differ depending on circumstances and how the managers view the economic opportunities. Although it can be demonstrated that changes in grades and discounts, as well as prices, are passed through the market channel from export elevator to farmers fairly rapidly, it cannot be proven exactly how that pass-through will occur, nor under what circumstances the export elevator will make the actual change that starts the chain reaction.[3]

The FGIS proposal for redefining the grade factor of BCFM has been defined only in general terms.[4] There are several alternative definitions and strategies for changing grades and standards. One or both of the factors could be made grade-determining. If one or both factors are grade-determining, there are several different possible limits for each numerical grade. Either one or both of the factors could be non-grade, optional criteria (available on request) or could be mandated to be automatically recorded as information on domestic certificates, export certificates, or both.

Since the specific definition and factor limits for the proposed grade change have not been decided and aggregate industry response to the various alternatives is unknown, the only logical approach is to develop alternative scenarios with accompanying assumptions. Twelve scenarios were developed and each scenario was evaluated using a set of potential impacts as a basis for evaluation [Hill and Bender, 1992]. Advice from operating managers and information from other surveys[5] and research have been used to develop the summary of impacts for each scenario. The firm budgeting model was used to estimate the change in incentives to clean on farms and at elevators.

Assumptions

Several assumptions are equally appropriate and essential for all of the analyses. These will be presented as background for evaluating each scenario individually.

1. Changes in grades, such as factor definitions, do not change quality directly; changes in quality come from actions by firms in response to grades and associated economic incentives.
2. Changes in grades will not shift profits from one sector of the industry to another. Profit levels in the industry are set by competition—competition between the farm sector and the elevator sector as well as competition among individual firms within each sector. If the market is operating in a competitive environment, the value of the products produced from corn minus competitive margins minus transportation costs generates prices paid to the next level back in the market channel.

   In the short run, a change in discounts or grade limits may increase or decrease discounts from a base price that does not immediately reflect the new value. But, given time for the market to respond, the base price and average price will adjust to a new equilibrium, and the prices paid in the industry must reflect value-in-use minus competitive margins and profits.[6] If there are structural imperfections in the market, such as differential information available to buyers and sellers, then changes in grades could shift market power and redistribute income by reducing these market imperfections.
3. Improved quality will have little effect on total world demand for corn, unless it results in substitution of corn for wheat or sorghum. Quality differences may shift preferred origin for an industry, but that shift will be countered by an opposite shift by other industries.
4. Changes in grades will not significantly alter U.S. market shares in the world corn market. An economically significant improvement in quality of U.S. corn may have the immediate effect of transferring volume to U.S. exporters away from our competitors. However, exporters in other countries will respond by changing price or quality in order to dispose of the corn they have already produced. The result may be a new combination of buyer–seller transactions and a shift in trading and transport patterns, but the total volume of corn traded will remain constant in the short run. In the longer run an increase in quality (and value) of U.S. corn will reduce the incentive for

further expansion in competing corn-exporting countries. The magnitude of this effect will be small compared to price fluctuations from other economic and political changes in the market (see the appendix for additional rationale).

5. In the aggregate, the price of corn reflects the value of the products derived from it—meal, starch, grits, etc.—minus costs of transportation and processing. Price and quality are balanced with value in each transaction within the limits of the information available to each buyer. Imperfect information increases the probability that cost will not be equated with value and less-than-perfect competition could result in inefficiencies and inequities.
6. For purposes of this evaluation it is assumed that the majority of U.S. corn exports will continue to be grade No. 3. If grade limits are changed, importers could change contracts, returning BCFM levels close to those in current No. 3 grade. This option was not included in the scenarios because it would have added too many alternatives to be evaluated in this report. Even if export contracts move quality from the new tighter restrictions, it is likely that the new contract would still require some improvement in quality.
7. Grain producers and grain elevator managers will respond to changes in grades when opportunities exist for increasing value or decreasing costs. It is assumed in these evaluations that the majority of corn in the market channel will be graded at some point and that corn that exceeds the factor limits will be assessed an implicit or explicit discount. While some managers, especially in the country, eliminate or reduce discounts by lowering the average bid price to all farmers [Bekric and Hill, 1991], that strategy removes incentives to improve quality and results in inequitable payments among farmers delivering different qualities.

Descriptions of Alternative Scenarios

The alternative approaches to redefining BC and FM have been grouped into seven categories, with additional variations on four alternatives resulting in 12 scenarios in total. The evaluation process was systematized by identifying a list of actions and impacts (see Table 20, on page 51) and assigning each item a qualitative change for each scenario.

Several definitions will simplify the terminology and reduce the potential for confusion in shifting among scenarios. BCFM is all material passing through the 12/64-inch sieve plus all non-corn material retained on the sieve. BC is all material (mostly broken corn) passing through the 12/64-inch sieve and retained on the 6/64-inch sieve. Fines is all material passing through the 6/64-inch sieve. CFM is all non-corn material readily removed by an appropriate scalper (yet to be designed). FM is fines plus CFM. TBC is the material passing through the 12/64-inch sieve. The 12 scenarios are described in the following pages. (A more detailed description and analysis is provided in Hill and Bender, 1992.)

Scenario 1.

BCFM as currently defined is retained in the grades, but the limit for each grade is lowered by 0.5 percentage point.

Grade	- - - *Proposed factor limits* - - - BCFM	Current BCFM*
1	1.5	2
2	2.5	3
3	3.5	4
4	4.5	5
5	6.5	7

*** Current limits and definition in U.S. grades.**

Scenario 2.

In this scenario BC and FM, defined according to the current FGIS proposal, are not included as grade factors; BCFM is retained as a grade factor at the present limits for each grade. The grades and factor limits are identical to 1991 official grades (see table in Scenario 1).

(a) BC and FM are included as additional information in the comment section of all domestic certificates. This is the procedure followed by USDA since May of 1989 on an experimental basis.

(b) BC and FM are optional criteria, available to all buyers on request.

Scenario 3.

BC and FM are defined according to the current FGIS proposal and are treated as two grade factors, with their sum *equal to* current levels of BCFM for each numerical grade. The ratio of FM to BC was selected to approximate the current ratio at the export elevator.[7] The elevator is assumed to measure both BC and FM on all receipts even though some elevators currently grade only in problem situations.

	- - - *Proposed factor limits* - - -			
Grade	BC	FM	Resulting BC + FM	Current BCFM*
1	1.5	0.5	2	2
2	2.3	0.7	3	3
3	3.0	1.0	4	4
4	3.8	1.2	5	5
5	5.3	1.7	7	7

*** Current limits and definition in U.S. grades.**

Scenario 4.

BC and FM are defined according to the current FGIS proposal and are treated as two grade factors, with their sum *less than* current levels of BCFM for each numerical grade. The ratio between BC and FM will approximate current levels at export elevators.

(a) 1-percent reduction in BC + FM:

Grade	--- *Proposed factor limits* --- BC	FM	Resulting BC + FM	Current BCFM*
1	0.8	0.2	1.0	2
2	1.5	0.5	2.0	3
3	2.3	0.7	3.0	4
4	3.0	1.0	4.0	5
5	4.3	1.7	6.0	7

*** Current limits and definition in U.S. grades.**

(b) Greater-than-1% reduction in BC + FM:

Grade	--- *Proposed factor limits* --- BC	FM	Resulting BC + FM	Current BCFM*
1	0.4	0.1	0.5	2
2	0.8	0.2	1.0	3
3	1.2	0.3	1.5	4
4	1.5	0.5	2.0	5
5	2.3	0.7	3.0	7

*** Current limits and definition in U.S. grades.**

Scenario 5.

BC and FM are defined according to the current FGIS proposal. BC is included as a grade factor; FM is included as a non-grade factor and the market uses a weight reduction. The market would set the discount for BC, probably using the current 1 cent or 2 cents per bushel per point. This discount rate for BC is approximately the same as the value of dockage for FM at the current price of corn. Limits on BC and FM are low enough that the sum of BC + FM is below the current BCFM levels.

(a) Dockage is calculated as a weight subtraction of 0.1 percent for each 0.1 percent FM starting at FM = 0. Results would be reported on the certificate, rounded to the nearest tenth.

	- - - Proposed factor limits - - -			
Grade	**BC**	**FM**	**Resulting BC + FM**	**Current BCFM***
1	1.5	0	1.5	2
2	2.5	0	2.5	3
3	3.5	0	3.5	4
4	4.5	0	4.5	5
5	6.5	0	6.5	7

*** Current limits and definition in U.S. grades.**

(b) Dockage is implemented by the market using a weight subtraction of 0.1 percent for each 0.1 percent FM starting at FM = 0.3. A cleaning penaltywould be needed to generate incentives for removing FM above 0.5. Results would be reported on the certificate rounded to the nearest tenth.

	- - - Proposed factor limits - - -			
Grade	**BC**	**FM**	**Resulting BC + FM**	**Current BCFM***
1	1.0	0.3	1.3	2
2	2.0	0.3	2.3	3
3	3.0	0.3	3.3	4
4	4.0	0.3	4.3	5
5	6.0	0.3	6.3	7

*** Current limits and definition in U.S. grades.**

Scenario 6.

BC is defined as the material passing through the 12/64-inch sieve and retained on the 6/64-inch sieve; material falling through the 6/64-inch sieve is called fines; CFM is defined as non-corn material readily removed by scalping.

(a) BC and fines are used as grade factors with limits equal to current BCFM; CFM is treated as dockage (i.e., weight subtraction) starting at zero. A cleaning charge would be needed to generate incentives for removing CFM.

		------ *Proposed factor limits* ------			
Grade	Fines	BC	CFM	Resulting BC + FM	Current BCFM*
1	0.2	1.8	0	2	2
2	0.4	2.6	0	3	3
3	0.6	3.4	0	4	4
4	0.8	4.2	0	5	5
5	1.0	5.0	0	7	7

*** Current limits and definition in U.S. grades.**

(b) BC is a non-grade standard required on official inspections and entered as information on the certificate. CFM is treated as dockage (i.e., weight subtraction) starting at zero; fines is a grade-determining factor starting at 0.2 percent for grade No. 1 and increasing by steps of 0.2 percent between each numerical grade. The level of fines in each grade is approximately equal to the level currently found in BCFM in the market channel. A cleaning charge would be needed to create an incentive greater than weight subtraction. All percentages are rounded to the nearest 0.1 percent.

	--- *Proposed factor limits* ---		
Grade	Fines	CFM	Current BCFM*
1	0.2	0	2
2	0.4	0	3
3	0.6	0	4
4	0.8	0	5
5	1.0	0	7

*** Current limits and definition in U. S. grades.**

(c) BC and fines are combined into a single grade factor TBC, which is defined as all material passing through the 12/64-inch sieve. CFM is defined as all material readily removed by an approved device, approximating results from commercial scalpers as installed in farm and elevator cleaners. TBC is included as a grade factor with maximum limits 1.0 percentage point below current grade limits for BCFM. CFM is treated as dockage (i.e., weight subtraction) starting from a zero base. A cleaning charge would be needed to generate incentives for removing CFM.

	--- *Proposed factor limits* ---		
Grade	TBC	CFM	Current BCFM*
1	1.0	0	2
2	2.0	0	3
3	3.0	0	4
4	4.0	0	5
5	6.0	0	7

*** Current limits and definition in U. S. grades.**

Scenario 7.

BC and fines are combined into a single grade factor TBC with limits 1.0 percentage point below current BCFM limits. CFM is listed as dockage with a weight subtraction. A cleaning charge for any value above zero, measured to the nearest 0.1 percent, would be needed to encourage removal of CFM. Breakage susceptibility will be measured and recorded on all certificates and will be considered as a non-grade standard requiring mandatory measurement. The grades would appear as follows:

	--- *Proposed factor limits* ---		
Grade	**TBC**	**CFM**	**Current BCFM***
1	1.0	0	2
2	2.0	0	3
3	3.0	0	4
4	4.0	0	5
5	6.0	0	7

Breakage susceptibility of ____% was present in this sample.

*** Current limits and definition in U.S. grades.**

Alternatives for Reducing Breakage

Changes in the definition and limits of BC and FM, or BCFM, were proposed to deal with a problem— excessive broken corn and fines— created by harvesting, drying, and handling methods. Since broken kernels and fines increase with each handling in the market, the problem is difficult to resolve after the dry corn enters the market. If the objective is to reduce the levels of BC and fines in the market channel, some incentives must be created to reduce breakage susceptibility by changes in variety, harvesting, and drying methods. Farmers are already shifting slowly to modified drying systems, in which kernel temperature is controlled. There are many drying technologies that reduce breakage susceptibility. For simplicity of exposition, these will all be referred to as *low-temperature drying*. It is assumed that a change in grades to encourage price differentials for breakage susceptibility will accelerate the change to low-termperature drying on farms. Elevators cannot easily convert to low-temperature dryers. There are two forms of incentives:

- ***indirect.*** Low limits and high discounts for fines will eventually force a search for techniques for reducing breakage during handling in order to avoid discounts in the market channel.
- ***direct.*** A test for breakage susceptibility included in the grades or standards will provide a direct incentive, if it is accompanied by a price differential.

Scenarios 1 through 6 create indirect incentives at best. The grades and standards proposed under Scenario 7 incorporate the incentives directly.

Evaluating the Impacts of Alternative Scenarios

Each scenario was evaluated on the factors listed in Table 20, where symbols are used to indicate a small increase (+) or decrease (–) or no effect (0). A double (++) or triple (+++) symbol indicates moderate or large impacts. The only quantitative estimates were derived from the budgeting models for a typical farm and elevator (Table 21). The net benefit for each scenario was converted to a qualitative indicator and entered as a cost of cleaning in Table 20. In the budgeting model, the base case (current grades) generates net benefits of $0.003 or $0.016 per bushel for farm and elevator cleaners, respectively. All other scenarios were compared against this base. The firm budgeting model [Meinders and Hurburgh, 1992] was configured as follows:

1. The on-farm assumptions were those pertaining to the rotary cleaner (Meinders and Hurburgh, 1992].
2. The elevator assumptions were those pertaining to the gravity cleaner, and the elevator was assumed to test for particle-size factors if the scenario was more restrictive than present grades.
3. Neither farm nor elevator would clean with two screen sizes; therefore the cleaner parameters would stay the same. In either case, the cleaning removes essentially all the FM.
4. The discount **rate** for BCFM and FM would be equal, at the current approximately 1.0 percent of price per percent over limits. Actual discounts in the market will change whenever the factor limits and definitions are changed.

Table 20. Summary of Economic Impacts from Alternative Scenarios—Separating BC and FM in Corn Grades

	Scenario 3	Scenario 4b	Scenario 5a	Scenario 6c	Scenario 7
Information accuracy and detail	+	+	+	+	+
Inspection costs					
Official grade	+	+	+	+	++
Private grade	+	+	+	+	++
Segregation and blending	+	+	0	0	+
Cleaning location					
Farm	0	+	0	0	0
Country elevator	+	++	++	+	–
Export elevator	0	++	++	0	–
Corn screenings					
Volume	+	++	+	+	–
Quality/value	0	++	0	+	0
Transport costs	0	++	+	+	–
Storability	0	++	+	+	++
Discounts to farmers	0	+++	++	+	+
Incentives for change					
Farmers	0	+++	++	+	++
Grain handlers	0	+++	++	+	++
Corn for milling					
Processing value	0	++	+	+	++
Export volume	0	+	0	0	++
Export quality No. 3 yellow corn					
Loaded quality	0	++	+	++	+++
Perceived quality	0	+	0	++	+++

0 = no effects; – = decrease; + = small increase; ++ = moderate impact; +++ = large impact.

The objective of the budgeting model was to estimate the change in incentives to clean if farmers and elevators wanted to keep their sales within the same nominal grade (U.S. No. 2 in the interior, U.S. No. 3 at export) under the proposed alternatives. These results were included in the qualitative summary of impacts for each scenario. Increases in incentives to clean are not necessarily profits for cleaning, but rather partial prevention of losses.

Only five of the 12 scenarios (3, 4b, 5a, 6c, and 7) have been selected for detailed evaluation in this publication. All 12 are discussed in detail in Hill and Bender [1992].

Evaluation of Scenario 3.

Including BC and FM as two separate grade factors associates additional information with numerical grades.

Scenario 3 would increase the cost of grading for official and private inspections. It would increase the cost of segregation and blending because this scenario has added one more factor on which blending must take place to meet grade specifications. Buyers will need to consider both factors in selecting numerical grades.

If the limits are set so that BC plus FM approximates the current levels of BCFM in the market channel, practices will probably remain unchanged. Country elevators, where BCFM is checked only when there is evidence of a problem, will continue the practice of averaging inbound loads and blending outbound lots to avoid discounting farmers' corn.[8] Discounts, incentives, and cleaning practices at the farm level would be unchanged. In many shipments, grain handlers will be able to meet the grade limits on both factors by measuring total BCFM because normal commingling prior to load-out will generate the average ratio of BC to FM. However, some country grain elevators will need to use slightly lower target levels of BCFM to avoid possible discounts in cases where the BC to FM ratio varies enough that one of the factors could exceed the grade limit.

The slightly lower target levels would require some additional cleaning, even though the average ratio of BC to FM in the proposed grades of Scenario 3 is similar to the ratio in No. 2 and No. 3 corn using current cleaning strategies. Export elevators would have sufficient flexibility in blending to meet the limits on the two factors without any increase in cleaning. Additional cleaning at the country elevator would result in a slight increase in the volume of screenings. The increased screenings would be absorbed in the local market with no noticeable impact on transport costs. The quality of corn screenings would be unaffected.

Farmer discounts would remain unchanged; farmers might be encouraged to make combine adjustments once they recognize the amount of FM that they are generating separately from BC.

Table 21. Summary of Cost–Benefit Model Results for the Five Scenarios for Corn Grade Changes

	- - - - - Benefits for cleaning (cents/bu) - - - - -				*- - - - - - Quality level after cleaning (%) - - - - - -*			
Scenario	Farm total	Farm change	Elevator[a] total	Elevator[a] change	Farm BCFM	Farm FM	Elevator BCFM	Elevator FM
Base	–0.3	Base	1.6	Base	Base	Base	Base	Base
3	–0.3	Base	1.1	–0.5	1.2	0.1	1.8	0.1
4b	1.3	1.6	4.4	2.8	1.2	0.1	1.8	0.1
5a	0.7	1.0	2.0	0.4	1.2	0.1	1.0	0.1
6c	0.7	1.0	2.6	1.0	1.2	0.1	1.0	0.1
7	1.2	1.5	2.6	1.0	1.1	0.1	1.5	0.1

Base quality for in-bound corn: farm = 2 percent BCFM; elevator = 3 percent BCFM.
[a]Country elevator, storing grain for six months or more.

However, there would be no economic incentives to change farm harvesting, drying, or cleaning practices. The psychological incentive might induce a slight improvement in quality. The firm budgeting model showed no change in farmers' net benefit from cleaning (a negative benefit of 0.3 cents per bushel) and a moderate decrease in net benefits for elevators (0.5 cents per bushel) relative to the base (Table 21).

The processing value of No. 2 or No. 3 corn would be unaffected. The effect on export volume and processing volume would be small since this scenario provides no new information about yields of grits or starch and exporters would be loading to the same grade limit. The loaded and perceived quality at foreign destinations would remain unchanged.

Evaluation of Scenario 4b.

The impact of this scenario would be quite large because the grade limits for BC and FM are over half of current grades (2 percentage points for No. 2 corn). There will be an additional cost of official and private grading and inspection relative to the current system with new sieves for the Carter-Day Dockage Tester. Information will be required on two factors instead of one. The separation would provide more information for the buyer, and No. 3 corn for export would contain less FM than under the current system.

Elevators blending to meet contract specifications—especially export elevators—would need to bin according to one additional factor to enable combining different levels of BC with different levels of FM to meet grade limits. Most export elevators have a sufficient number of bins to allow the necessary segregation, but each additional factor requires extra time, expertise, and expense to achieve the perfect blend. There will be instances where the perfect blend cannot be achieved and the exporter will have to deliver better-than-contract quality on one or more factors. This also adds to the cost of marketing that will need to be recovered from importers or producers.

The costs of cleaning, blending, and handling and the frequency of producer discounts would significantly increase. More cleaning would be required at interior elevators and at the ports in an attempt to achieve the lower limits on BC and FM. The limits are below the levels generally created during normal handling, so cleaning would be required at each point in the market channel to meet No. 2 grade. Current capacity and cleaning strategies would not be adequate.

The volume of screenings would increase, but the amount of CFM removed during cleaning would remain the same. This would increase the proportion of broken corn in screenings, thus increasing the quality of screenings. The cost of transport would increase as a result of the larger volume of screenings, often located outside the geographical area of consumption.

Benefits from this scenario include improved storability throughout the market channel due to the reduction in levels of BC and FM. At this level of BC plus FM, nearly all farmers would be affected. The incentive to reduce BC and FM would be felt throughout the market channel. The difficulty of meeting the very low grade limits would create an incentive for country elevators to pay premiums for corn with resistance to breakage. Only corn with low breakage susceptibility could be handled without exceeding the grade limits for No. 2 and No. 3 corn. The budgeting model showed an increase of 1.6 cents per bushel in the benefits from cleaning on the farm under this scenario. The incentives for cleaning at the elevator increased by 2.8 cents per bushel (Table 21).

The quality of corn would be improved, and value of corn for milling would be increased. The increase in processing value and improvement in perceived quality would make U.S. corn more competitive in the export market for milling uses, thus increasing export volume. The lower levels of BC plus FM in No. 3 corn would reduce BCFM in exported corn by 2.5 percentage points, improving loaded quality. The reduction in BC plus FM in No. 3 corn would be sufficient to be noticeable at foreign destinations, thus improving perceived quality.

Evaluation of Scenario 5a.

Defining FM as a non-grade factor with discounts starting at zero, reported to the nearest tenth of a percent, provides more accurate and detailed information on the most objectionable segment of BCFM—the fines plus non-grain impurities—and restricts that factor to levels below those in current grades.

There would be an additional cost of grading in official and private inspections because FM and BC levels would need to be identified. Since the zero FM limit is non-operational from the suppliers' viewpoint, corn would not be binned according to FM but only according to BC. Thus, this scenario would not add binning or blending costs.

The zero base rewards cleaner grain at all levels by a weight subtraction for any level of FM above zero. Equity among farmers would be increased because farmers currently delivering No. 1 or better corn would receive a higher net price under the proposed grades compared to farmers currently delivering 2 percent or 3 percent BC and FM. The zero base would create an incentive for every farmer and grain handler to maintain cleaner corn. However, with no charge for cleaning, the 1 percent weight deduction for each 1 percent of FM is an inadequate incentive to persuade farmers to install a grain cleaner or reduce FM to zero. Although farmers can reduce levels of FM through improved harvesting practices,[9] a one-for-one weight reduction is still neutral—there is no cost, except transport, to farmers who deliver excess FM.

Current cleaning capacity at interior elevators is probably adequate to meet the limit of 2.5 percent BC for No. 2 corn in Scenario 5a. However, lowering FM levels to approach zero would require additional cleaning at those elevators with cleaners installed (64.2 percent in the survey)[10] and installation of new cleaners at other elevators. Each handling in the market channel would add fines, requiring additional cleaning to reduce FM toward zero FM. Elevators will also view FM as neutral except for transport costs. Even though export elevators would receive less BC and FM than under present grades, receipts would be above zero percent FM, and subsequent handling would add more.

Cleaned corn in the market channel using current cleaning strategies contains an average of 1.4 percent BC and 0.4 percent FM.[11] Current cleaning strategies at the port will not achieve a ratio of 2.5 percent BC and zero percent FM in No. 2 corn or of 3.5 percent BC and zero percent FM in No. 3 corn. In experiments at export elevators, the only cleaning strategy that was effective in removing more of the fines was the use of a secondary cleaner.[12] Changing flow rates or screen sizes changed the total quantity of BC plus FM in the cleaned corn but did not significantly change the ratio of BC to fines. The cost of installing a secondary cleaner or changing cleaning technology throughout the industry to achieve zero percent FM would be prohibitive. The most likely response by exporters would be to clean to meet the 3.5 percent limit on BC and take the discount or weight dockage on the excess FM. An extremely high discount for FM, out of proportion to the effect its presence would have on value, would be required to induce interior or port elevators to install secondary cleaners.[13]

More cleaning at the port would create more screenings, adding to the cost of cleaning and transportation. Quality of screenings would remain unchanged under the assumption that cleaning technology will remove BC and FM in proportions approximating the current ratio. Removal of the smaller particles (fines and FM) would improve storability in the market channel as well as on the farm.

Since zero percent FM cannot be achieved or maintained in the market channel, any corn tested would receive a discount and conceivably all farmers could be discounted. Farmers in our survey strongly supported the concept of separating BC and FM, and 37 percent supported a zero base for beginning FM discounts.[14] When asked if they could lower current levels of FM delivered to the elevator, 90.8 percent indicated that they could achieve lower levels of BCFM by improved weed control, harvesting practices, or drying methods.[15] The low levels of FM present in farm-delivered corn (0.22 percent in

1977 study)[16] would allow many country elevator managers to ignore the FM factor and not test most receipts. However, the potential for a discount would be an incentive for all farmers to improve their practices, and even infrequent application of a discount would encourage changes in practices by farmers with high levels of FM. The budgeting model showed an increase of 1.0¢ per bushel in returns to cleaning on the farm; 0.4¢ per bushel at the elevator (Table 21).

The effect on milling quality will be small as a result of less FM in deliveries from farms and elevators. The foreign processors are not likely to see enough additional value in the small reduction in FM to justify an increase in volume purchased.

The effect on loaded quality will be small, and no effect on perceived quality at foreign destinations, since the corn will be handled several times before use, and BC and FM will increase with each handling.

Evaluation of Scenario 6c.

The similarity in the composition of BC and fines and the continuous gradation of particle sizes of corn from 14/64-inch to 4/64-inch to dust suggests that the distinction between BC and fines at 6/64-inch is largely arbitrary. Interviews with domestic and foreign processors have identified only a limited demand for information on particle size of broken kernels. The grade factor for Scenario 6c combines broken corn and fines into one factor called Total Broken Corn (TBC). This includes all material passing through the 12/64-inch sieve. It is similar in nature to the current factor BCFM except that coarse FM is separated as a non-grade factor and listed as dockage with a weight subtraction plus a cleaning charge for any value above zero percent. Combining BC and fines into the one grade factor of TBC eliminates the cost of grading, segregating, and blending on both BC and FM as required under scenarios where BCFM is separated into two grade factors. The limits on TBC (including fines) are less than current limits on BCFM, increasing discounts and incentives to clean.

Reporting CFM as a weight subtraction (and/or discounts) starting at zero provides more information to buyers about the quantities of non-corn in the shipment. It rewards all efforts to reduce CFM levels as close to zero as possible, but allows the market to select the acceptable levels by adjusting the base for discounts beyond the weight subtraction. Although CFM represents a small percentage of the total weight in domestic and export markets, the cost of transporting material of little value offers an opportunity to increase marketing efficiency by encouraging its removal as close to the source as possible.

Official inspection costs will be increased by the need to determine CFM. Country elevators doing their own grading would also experience an increase in costs if they determine CFM separately from BCFM. This scenario will not require additional segregation since there is only one grade factor.

Cleaning will increase only at the country elevator. The lower limits on TBC will not induce farmers to purchase new cleaning equipment. The budgeting model showed an increase of 1.0 cent per bushel in returns to cleaning on the farm and 1.0 cent per bushel at the elevator (Table 21). The export elevator will receive corn with 1.0 percent less TBC, and therefore exporters can load corn with 1.0 percent less TBC without changing their current cleaning practices.

The quantity and transport cost of screenings will increase and quality will improve as well. Lower limits on TBC will improve storability by reducing the amount of fines.

Loaded quality and processing value will be increased by the 1.0 percentage point reduction in TBC relative to current levels of BCFM. The improvement will not affect export volume because breakage during unloading will mask the reduction in TBC at destination. Perceived quality will be improved only by the reduction of CFM. Corn will contain some non-corn material passing through the scalper.

Evaluation of Scenario 7.

This scenario includes TBC and CFM as defined under Scenario 6c. TBC is a grade-determining factor with limits 1 percentage point below current limits on BCFM. CFM is set at zero with a weight subtraction and a suggested cleaning penalty for each tenth of a percent. CFM will be measured and recorded to the nearest 0.1 percent. In addition, breakage susceptibility will be measured and recorded on all certificates as a non-grade standard, requiring mandatory measurement on all official grades.

BC and fines are combined into one factor (TBC) because the difference between them is primarily one of particle size. Differences in chemical and physical properties are correlated with particle size in an almost continuous function. Protein and fiber content increase and starch content decreases as particle size decreases. There is no one sieve size that generates a significant difference between fines and BC on all characteristics. Any BC creates problems of storability, handling, and milling, so it is treated as one factor regardless of particle size in this scenario. The same result could be achieved by replacing TBC with a factor defined as the percent of whole unbroken kernels. However, the ease of measurement argues for a definition based on a sieve separation.

The unique characteristic of this alternative is the inclusion of a breakage susceptibility test. This test would be mandatory for all official inspections. Country elevators might be slow to adopt this as a grading factor in their farmer receipts; however, the advantages in terms of reduced breakage and better storability, added to the opportunity to sell premium grade corn into the milling industries, should move the industry to a system of price differentials for differences in breakage characteristics.

In this analysis of impacts it is assumed that country elevators and processors will incorporate some measure of breakage susceptibility into their system of premiums and discounts. Many firms (especially dry millers) are already using indicators of breakage susceptibility and implementing price differentials for corn that meets standards that will assure low breakage during handling and higher yields of processed products. Some country elevators have also found it economically feasible to offer premiums for corn with low stress cracks. A measure of breakage susceptibility, or some other indicator of damage resulting from high temperature drying, would encourage the current trend towards low-temperature drying and create incentives for managing harvesting and drying so as to minimize breakage later in the market channel. Measures of hardness or density are not an acceptable substitute. High-density, hard kernels will still perform poorly if subjected to high temperatures during drying.

Farmers delivering corn that has not been subjected to drying will find it easy to meet lower limits on TBC and should not be discounted for breakage susceptibility. Levels of breakage susceptibility or percent stress cracks should be low enough to avoid discounts on freshly harvested corn. The effect of genetics or harvesting methods on breakage susceptibility is smaller than the effect of drying. However, the damage is multiplicative, and adding combine damage to dryer damage results in defects that exceed the simple sum of the two effects (Figure 5). The breakage susceptibility test (or a proxy such as stress cracks) can be used to identify corn that will have higher yields of starch and dry milling products as a result of careful handling. Farmers delivering corn that has been dried and stored will see additional discounts if the corn has been dried improperly. However, farmers can avoid discounts by adopting better harvesting methods and low-temperature drying on the farm. The budgeting model showed an increased return to cleaning of 1.5 cents per bushel on the farm and 1.0 cent per bushel at the elevator (Table 21).

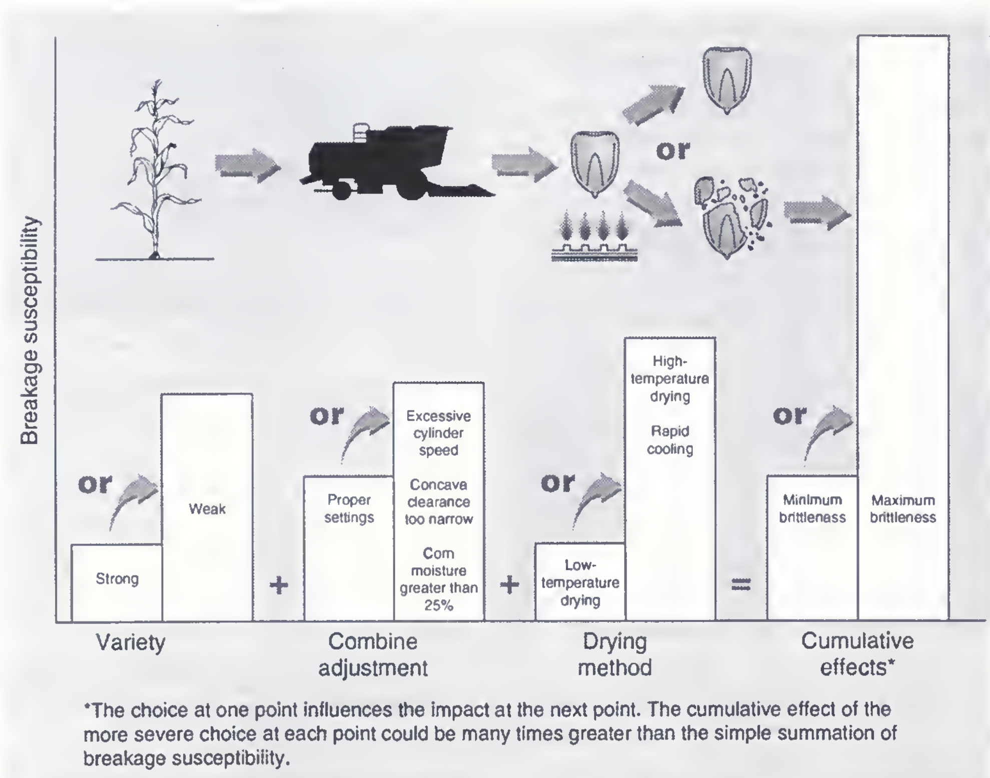
This scenario provides additional information that reflects end-use value. Although breakage susceptibility tests are not perfectly correlated with the amount of BCFM created in the market channel, high breakage-susceptibility values will generate problems during subsequent handling. Lower values will enable shippers to meet the lower limits on TBC with less cleaning. Within most of the domestic market the impact of the breakage test will be on the yields for wet and dry milling products, rather than on the creation of breakage during handling. In the export market, the reduction in dust and broken kernels may be as important as the improvement in value for processing. The breakage susceptibility test is correlated with milling value. Corn resistant to breakage (dried at lower temperatures) will give higher yields of products in wet and dry milling.

The breakage-susceptibility test will result in a significant increase in inspection costs for official grades as well as private grades compared to the current inspection system. Tests for breakage susceptibility will require new technology such as an impact tester or stress crack determination. A simple measure such as percent of kernels with stress cracks can serve as a proxy until a more sophisticated objective test can be developed. To the extent that these measures are used at the country elevator, it will be a major change in their grading and analytical techniques, adding to the time and cost of grading. Measuring and recording CFM as separate information will also add to the cost of grading.

We assume that some buyers will specify limits on breakage susceptibility and that the market will establish price differentials where breakage susceptibility is an important characteristic. Elevators may choose to segregate on factors of breakage susceptibility as well as on the factor of TBC. Segregation and blending, however, take place in the market channel only in response to positive economic incentives. Since the presence of a factor in the grades does not force segregation, the market must encourage it. As incentives develop, segregation costs will increase as more elevators choose to segregate.

The 1 percent reduction in TBC relative to current BCFM limits will not induce farmers to purchase grain cleaners. Those farmers delivering higher levels of BC and fines from storage

Figure 10. Relative magnitude of factors causing breakage susceptibility.



Source: Hurburgh, 1992.

may receive additional discounts. Lower levels of CFM can be achieved by combine adjustments. Farmers using high-temperature dryers will also receive discounts on the test for breakage susceptibility. This incentive will induce farmers to shift to new varieties and low-temperature drying, reducing the levels of TBC below the limits for No. 2 corn. In the longer run, the frequency of discounts will be significantly reduced.

The country elevator and export elevator will also experience decreased cleaning requirements as a result of receiving low breakage corn, even though the limits on BC plus fines has been reduced by 1.0 percent. The extra cleaning required to meet the lower limits on TBC will be eliminated once the volume of low-breakage corn is increased. Less cleaning will reduce the volume of corn screenings in the market, but farmers will also be delivering less CFM. The quality of corn screenings is not expected to change significantly. Transportation costs for screenings will decline with the reduction in the volume and with screenings located in the origin area rather than at export. Storability characteristics will be increased not only for the foreign buyers but throughout the market channel, starting at the farm storage bin. Cleaner corn and lower drying temperatures will increase storage life and aeration costs.

Farmers will receive a strong incentive to select varieties, drying technology, and handling practices that produce low-breakage corn. The price differentials for low-breakage corn may even induce some country elevators to alter their drying strategies. The lower limits on TBC will also provide an incentive for country elevators to improve their handling and drying practices and to deliver cleaner corn into the market channel. However, with higher quality corn to work with, they will have the opportunity to deliver better quality with less total effort and cost.

Milling quality for both wet and dry milling will be increased not only by the reduction in TBC and CFM, but also because low-breakage corn yields more of the high-valued products in both the wet- and the dry-milling industries [Weller et al., 1988; Hill et al., 1991a]. This increase in the domestic quality will be noticeable and will have a positive impact on yield of processed products. The same relationship will hold for foreign buyers and should attract a larger volume of U.S. corn into the high-priced milling markets. The increased value of corn for milling should be reflected in prices. Even the domestic feed market will experience some benefit from cleaner corn, better storability, and reduced risk of mold. The export feed markets will also benefit from the reduced dust that accompanies low-breakage corn.

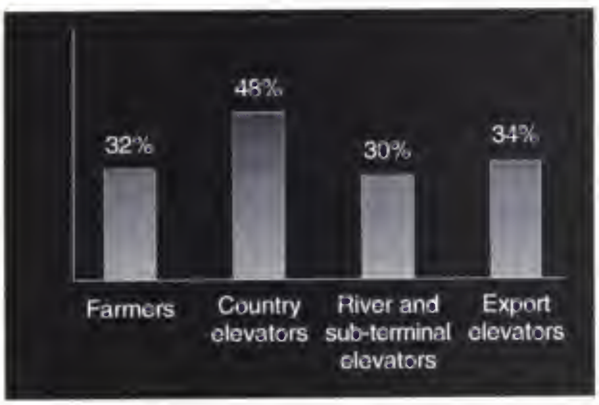
The export quality of No. 3 yellow corn will be dramatically increased with the reduction in TBC and CFM. The quality and perception of quality at destination will be noticeably increased because of the low-breakage susceptibility characteristics. Handling in the market channel from port elevator to foreign processing plant will not generate the amounts of dust and broken kernels that have been experienced in the past. Improved harvesting and drying can produce corn with a clean, bright color, distinctly different from most No. 3 corn, which is usually coated with corn dust by the time it reaches the processing plant in the country of destination. Germination (a quality indicator often used by wet milling) will also be significantly better.

Support for Separating the BCFM Factor

Attitudes Toward Change

Support for changing the definitions of BCFM in corn grades must come from those segments most affected by the change—producers, interior elevators, export elevators, and buyers. Although a popularity poll should not be the sole criterion for what is best for the industry countrywide, the opinions of those affected must be recognized and evaluated. These opinions, obtained through mail surveys, showed similarity between farmers and marketing firms in the levels of support for separating BCFM (Figure 11).

Figure 11. Percent of respondents supporting a separation of the BCFM factor.



Opinions of Farmers

Since foreign material and broken grains have received so much attention in foreign complaints and legislative action, the survey asked farmers for suggested ways of reducing FM in both corn and soybeans. The three most popular actions were (1) legislative prohibition against blending and adding FM to clean grain; (2) introducing premiums for lower levels of FM content; and (3) separating BC from FM (Figure 12). Less than 10 percent of the farmers suggested lower limits on BC and FM.

Preferred Method for Reducing Discounts

A majority of farmers favored legislative prohibitions against blending foreign material with grain. In the three states surveyed (Indiana, Iowa, and Illinois), 58 percent of the farmers considered this an effective measure for reducing FM (Table 22). The question on the survey did not differentiate between blending FM from independent sources and reblending material removed from corn at an earlier point in the handling sequence. It was assumed that farmers favoring prohibitions would include both sources in the prohibitions. In addition (or as an alternative), about half of the farmers in those three states wanted to introduce premiums or subsidies for FM content below contract grade to motivate farmers to deliver cleaner corn and soybeans. Changing the grade factor definitions to separate BC from FM and treat BC differently from FM was supported by 32 percent of farmers.

Figure 12. Alternative strategies for improving corn quality.

Base Level for Discounts

Farmers desiring the separation of BC and FM were asked to indicate the percent of FM that should be allowed before the market applied a

Table 22. Preferences of Illinois, Iowa, and Indiana Farmers for Alternatives for Reducing FM in Corn and Soybeans, 1986

List of alternatives[a]	% of farmers supporting
1. Legislate prohibition against blending and introduction of FM.	58
2. Provide premium (subsidy) for FM below contract grade.	51
3. Lower allowable limits in the standard for FM.	10
4. Raise discounts without changing grade limits.	6
5. Separate BC and FM.[b]	32
6. Leave system as it is.	7

[a] Respondents were allowed to check more than one alternative. [b] A check for "discount per point for FM above 0 percent," for "discount per point for FM above [x] percent," or for any discount recorded in the question was counted as support for separation of BC and FM.

discount. Remarkably, the limit suggested by many farmers was zero percent: 37 percent of the respondents from the three states suggested that any FM in the grain should be discounted (Table 23). Another 17 to 21 percent of the farmers, who did not choose to start discounts at zero percent, suggested starting discounts at levels below the current limit for BCFM in No. 1 corn. The remaining farmers chose to separate BC from FM and supported 2, 3, and 5 percent limits for discounts. These limits are familiar numbers for farmers, since they correspond to the current limits for BCFM for No. 1, No. 2, and No. 3 grades, respectively.

Although expressing dissatisfaction with the lack of premiums, farmers clearly understood the importance of price differentials to encourage quality improvement. When asked if they would like to eliminate all discounts so that all farmers would receive the same price, 61.4 percent of Illinois farmers said no. The percentages for Indiana and Iowa farmers were 55.8 and 68.3, respectively.

Opinions of Interior Elevator Managers About Changing BCFM

Each elevator manager was asked for an opinion on the proposal to separate BC and FM. The open-ended question asked for a short-essay answer. The answers were categorized roughly into positive (in favor of separation), negative (not in favor), and indifferent (including those with extensive qualifications to positive or negative and those neutral or undecided).

Each of the three categories of responses was divided into three subcategories, creating a total of nine subcategories of responses (Table 24). Conclusions about opinions to support or oppose the proposal were based

Table 23. Maximum Limit for FM Without Discount Suggested by Farmers Who Recommended Separating BC from FM, 1986

Factor limit	Illinois		Iowa		Indiana		Three-state total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
0.0	84	31.7	97	37.7	70	41.4	251	36.9
0.5	4	1.5	2	0.8	4	2.4	10	1.6
1.0	41	15.5	40	15.6	29	17.1	110	16.1
1.5	5	1.9	2	0.8	2	1.2	9	1.3
2.0	54	20.4	44	17.1	26	15.4	124	17.6
3.0	32	12.1	26	10.1	16	9.5	74	10.6
4.0	6	2.2	9	3.5	3	1.8	18	2.5
5.0	38	14.3	33	12.8	19	11.2	90	12.8
6.0	0	0.0	1	0.4	0	0.0	1	0.1
7.0	1	0.4	3	1.2	0	0.0	4	0.5
Total	**256**	**100.0**	**257**	**100.0**	**169**	**100.0**	**682**	**100.0**

largely on the three general categories of positive, negative, and indifferent, but the additional breakdown into subcategories provides a partial explanation for differences in attitudes.

A high proportion (46.6 percent) of the 416 interior elevator respondents supported the proposal to separate BC and FM; 31.5 percent were opposed to the proposal; 21.9 percent were indifferent. There was more support for change from country elevator respondents (47.6 percent) than from the river, subterminal, and "other" elevator respondents (30.5 percent).

The majority of the positive responses fell into subcategory 2—"BC and FM are not the same and discounts should reflect value." Although subcategory 3 (Table 24) had the highest percentage of responses, that category included several different reasons. Negative responses were about equally distributed between "would cost elevators too much" (6.5 percent) and "would cost farmers too much" (5.5 percent). Fewer than 4 percent of the respondents claimed not to have enough information to take a position.

Attitudes by Type of Firm

The attitudes toward the proposal to separate BC and FM differed among types of elevators. Because the number of responses was small, the categories of river, sub-terminal, and other elevators were combined for a comparison with country elevators—those dealing most directly with farmers. Several points are worth noting in that comparison.

1. While nearly 22 percent of river and sub-terminal elevator respondents expressed concern about the potential cost to farmers, only 4.6 percent of the country elevator managers listed cost to farmers as a reason to oppose the proposal.

Table 24. Opinions, by Type of Elevator, on the Proposal to Separate BC and FM, 1989

	Opinion category[b]	Percent of responses[a]: Country elevator	Percent of responses[a]: River, sub-terminal, and other	All respondents: Number	All respondents: Percent
Positive	(1)	5.1	4.4	21	5.0
	(2)	16.8	17.4	70	16.8
	(3)	25.7	8.7	103	24.8
Negative	(4)	6.1	13.0	27	6.5
	(5)	4.6	21.7	23	5.5
	(6)	19.6	17.4	81	19.5
Indifferent	(7)	8.9	13.0	38	9.1
	(8)	3.5	0.0	14	3.4
	(9)	9.7	4.4	39	9.4
All respondents	Number	393	23	416	—
	Percent	94.5	5.5	—	100.0

[a]The 143 respondents who did not indicate an opinion were not included in this analysis.

[b]Positive response: Respondent agrees that BC and FM should be separated.
(1) Separation would improve U.S. grain trade.
(2) BC and FM are not the same and discounts should reflect value.
(3) Miscellaneous other positives not falling into categories (1) or (2).

Negative response: Respondent disagrees that BC and FM should be separated.
(4) Proposal would cost elevators too much in equipment and time.
(5) Proposal would cost farmers too much due to greater discounts.
(6) Miscellaneous other negatives not falling into categories (4) or (5).

Indifferent response: Response could not be categorized as positive or negative.
(7) Indifferent to proposal; would not affect my elevator.
(8) Do not know enough about proposal to have formed an opinion.
(9) Miscellaneous, such as "not needed" or not falling into categories (7) or (8).

2. An indifferent attitude (category 7) was more prevalent among river, sub-terminal, and "other" elevator managers than among country elevator managers (13.0 percent compared to 8.9 percent). Many of the managers in the indifferent category explained that they thought the change would not affect the profitability of their operation or their current practices.
3. The percentage of positive responses was slightly higher for country elevators (46.6 percent) than for river and sub-terminal elevators (30.5 percent).

In the comment section of the questionnaire, many of the country elevator respondents in the indifferent category stated that implementation of the proposal would not affect them in any significant way and that they would be willing to go along with whatever is mandated. Many reported that BC and FM are not a big problem for them. Other comments of interest included several country elevator respondents' suggestion that the problem was caused by export elevators when loading corn for export. On the other hand, many respondents felt that corn buyers should be willing to pay for high-quality corn and to provide the incentives for change.

Factors Influencing Attitudes

Many factors influence opinions and attitudes: facts, impressions, past experience, and the influence of others. The mail survey provided data about opinions but no information about their psychological bases. To help in explaining the different opinions regarding the proposed grade change, characteristics of each elevator were recorded and statements of their managers about the advisability of separating BC and FM were classified into nine categories of support or opposition to the proposal. Six independent variables were tested for their influence on the nine categories of managers' responses (Table 24). The variables were (1) size of operation as measured by elevator capacity; (2) percentage of shipments discounted for excess levels of BCFM; (3) percentage of corn sold to processors; (4) percentage of corn sold to export elevators; (5) percentage of corn sold to river elevators; and (6) turnover ratio as an indication of the relative importance of corn in the makeup of the elevator's income.

Only one of these variables (percentage of shipments receiving discounts) showed a significant relationship with the opinions of the respondents toward separating BC and FM. If any of the other variables influenced the managers' opinions, the influence was concealed by other factors.

The frequency of discounts has a direct influence on the income and profitability of grain merchandising. Elevator managers with frequent discounts for BCFM were expected to be more interested in changing the system on the chance that the changes might reduce the frequency and the severity of discounts. Those elevators that supported separation of BC and FM because the two components have different value reported that 12 percent of their shipments had been discounted—nearly twice the average of all respondents. Some other differences were evident from Table 24 but cannot be matched with any logical explanation. For example, those elevator respondents that were indifferent to the proposal reported that an average of 9.7 percent of their shipments had been discounted—the second highest level of the nine categories. The lowest percentage of discounts (there were three categories between 4.0 and 4.2 percent) was distributed among the positive "it would improve trade," the negative "miscellaneous reasons," and the indifferent "inadequate information to make a decision." These data do not provide the basis for explaining differences in the opinions expressed by the managers.

Opinions of Export Elevator Managers About Changing BCFM

Just over one-third of the export elevator managers supported the proposal to separate the BCFM factor; an equal number opposed the action. Twenty-nine percent stated they were indifferent or declined to answer that question. Comments ranged from "great idea!" to "not feasible."

A majority of the respondents who supported the proposed revision in grades stated that it would give the buyer more information. Many of the respondents who opposed the proposal were worried about an increase in operating costs without substantial increase in value. Two of the respondents (5.5 percent) thought the change would hurt producers.

Factors Influencing Attitudes

The attitudes toward the proposal might be influenced by the characteristics of the individual export elevator, such as size, corn volume, location, and volume of screenings marketed. Several of these relationships were tested using analysis of variance. The average grain storage capacity of elevator managers who favored the proposal was 5.3 million bushels. The average grain storage capacity of managers who opposed the proposal was 5.5 million bushels. Those who were neutral, undecided, or indifferent operated slightly larger elevators, with an average capacity of 7.8 million bushels. Size apparently had little influence on attitudes.

Managers of the export elevators who supported the separation of BC and FM handled a lower volume of corn than those who opposed the proposal. The average corn volume was 89 million bushels for managers expressing disapproval of the proposed change, 43 million bushels for those who approved the idea, and 73 million bushels for respondents who were indifferent or expressed no opinion.

There were also some geographic differences in the opposition to the proposed change. Seventy-three percent of the export elevators whose managers expressed disapproval were located in the Pacific and Lakes regions, while 80 percent of the approval ratings came from respondents located in the Atlantic and Gulf regions. The indifferent responses were largely located in the Gulf and Lakes regions.

The importance of corn relative to other grains appeared to be slightly associated with approval or disapproval of the proposed change, with corn volume averaging 46.1 percent of total volume for those elevators whose managers approved and 59.5 percent for those whose managers disapproved.

The average volume of screenings marketed in 1989 by managers opposing the change was 25,450 tons, compared to 21,050 tons for those supporting the idea of separating BC and FM. However, those supporting the change reported significantly more screenings per 1,000 bushels handled than the other elevators—0.5 ton of screenings per 1,000 bushels handled (1.7 percent) for those supporting the proposal, compared to 0.3 ton per 1,000 bushels handled (1.0 percent) for the group opposing the change and also for those who were indifferent.

Summary

None of the scenarios will significantly increase export volume or market share, although three of the five scenarios would result in improved quality in the export market. In a competitive market, higher value will be reflected in higher prices. The more difficult question is the balancing of the value of information against its cost. Several of the scenarios provide only a marginal increase in economically important information—scenarios 3, 4b, and 5a provide information about particle size of a mixture of corn and non-corn materials. Scenarios 6c and 7 provide more detailed information by separating CFM from broken corn.

The strongest incentives are accompanied by the greatest number of discounts but the greatest potential for improvement in quality. Equity in payments to farmers is best achieved with low limits on each factor and narrow steps between grades. This results in more severe discounts for more farmers, but equity requires that there be price differentials among producers according to the value of the crop that they deliver. In a competitive market, lower prices for poor quality will be offset by higher prices for good quality.

Scenario 3 results in no measurable improvement in corn quality. In contrast, Scenario 4b provides sufficient incentives to justify the fixed cost of a new cleaner. Scenario 4b improves quality by a significant reduction in BC and FM, but at a high cost of cleaning and discounts. The lower limits would probably require purchase of additional cleaning capacity. The combined effect of lower aeration costs, better storability, and discounts on BC and FM required to meet this restrictive grade limit would justify additional cleaning.

The most promising alternatives are Scenarios 6c and 7. Scenario 6c controls BC with numerical grade, reduces maximum limits for each grade below current levels, and differentiates among corn and non-corn material. Inspection procedures in this scenario are more complex than under current grades but less demanding than scenarios that include BC and FM. Although Scenario 6c does not differentiate BC according to particle size, it still provides incentives to improve quality.

Scenario 7 would have the greatest positive impact on quality by combining lower limits on TBC with information about breakage susceptibility. The impact will be greatest in processing industries, although even feed manufacturers prefer clean, unbroken corn with a minimum of dust. Importers will see a significant quality improvement. This scenario will entail the largest increase in inspection costs, requiring new equipment and new methods. Cleaning and storage costs at the elevators will decline. Farmers will face additional discounts on corn dried and stored on the farm, but better farmers will be able to meet the grade limits and avoid these discounts after they have adopted appropriate varieties, harvesting technology, and drying methods. The breakage test accompanied by appropriate price differentials would generate sufficient incentives to meet the objective of cleaner corn and improved quality.

Creating two grade factors of BC and FM (both primarily comprised of broken corn) differentiated only on the basis of particle size provides little additional information about the value of the lot while increasing the cost of grading, segregation, and blending. It also will increase the number of factors that could receive discounts, depending on the market response. In contrast, the separation of the sample into coarse FM (defined by mechanical sieving) and BC increases information for determining value, adds little to the cost of grading, does not require segregation or blending in the market, and places little economic burden on producers since it constitutes such a small proportion of the grain delivered. Once the objectionable material is removed from the grain, there is little opportunity for reintroduction of coarse FM during handling and transport through the market channel. Adding a factor to measure the percent of CFM separate from the percent of BC permits the identification of non-corn material larger than 12/64-inch. The grades of most other countries competing in the international corn markets contain a factor called impurities that results in a similar separation. Some non-corn material passing through the scalper would remain with the corn portion of the sample.

The requirement that changes in grain grades be justified by economic benefits that exceed costs is an unrealistic expectation based on a misconception about the purposes of grades and standards. No single grade factor, definition, or factor limit can be proven to significantly alter farm income, export volume, or competitiveness in international markets—that is not the purpose of uniform grades. Economic analyses have provided no evidence that past changes in definitions or grade limits have influenced market shares, farm prices, or income distribution. No one has systematically evaluated the structure of current grades to determine if each factor meets the criterion of value exceeding cost. This analytical void is the inevitable result of the impossibility of aggregating costs and benefits associated with any one factor or definitional change without introducing an unacceptably large number of simplifying assumptions.

Aggregate, quantitative comparisons of costs and benefits cannot be used to prove that there will be a net positive benefit as a result of lowering the limits on BCFM or separating BC and FM as an isolated regulatory change by FGIS. Aggregate statistical data about sales volume, prices, or incomes are not adequate to prove net gain or loss from a change in grades.

The same insurmountable obstacle is present in any attempt to quantify costs and benefits resulting from one individual factor in the current grades; it cannot be proven that any one grade factor has generated positive net benefits. Which of the current factors have increased exports, changed farm income, or raised the base price for corn? Is there any proof, or even supporting evidence, that removing heat damage or lowering test-weight limits would damage market shares? Moisture was removed as a grade factor for corn in 1985, and the industry moved from a 15.5 percent moisture base for No. 2 corn to a 15.0 percent base. No one has yet provided conclusive evidence that this change decreased farm income, raised the base price of corn, or reduced export volume (despite warnings of lost exports by some importers). It was not an oversight when the 1986 and 1990 amendments to the Grain Standards Act did not include in the purposes of grades and standards "increasing farm income" and "increasing export volume." The benefits from national grades and standards derive not from any ***one*** factor, definition, or grade limit, but from having a ***system*** to provide uniform measurements of quality. The purpose of uniform grades is to facilitate communication about value, thereby decreasing transaction costs, creating incentives for quality improvement, and allowing price differentials to direct each quality into its highest valued use.

The decision to change grades must be based on an evaluation of whether the change meets the six purposes of grades that have been incorporated into the U.S. Grain Standards Act. The definition of factors and the structure of grades must be based on logic, consistency, and their contribution to an efficient marketing system. Changes are indeed needed to improve communication, equity, incentives, and marketing efficiency, but industry participants should not be misled into making changes with the expectation of major changes in income and market share.

The goal of changes in individual factors and limits should be to move toward the ideal system of grades and standards. This requires that the ideal grade be developed to provide the frame of reference for changes implemented at different points in time. No factor should be evaluated in isolation from the total system or from a set of "ideal grades." This report violates that principle by focusing only on the factors of BCFM and breakage susceptibility in developing a set of recommendations. However, the recommendations given in the following pages are based on the authors' implicit set of "ideal grades" developed from previous research and experience as well as the results of the narrowly focused research on BCFM [Hill, 1991].

Recommendations

The qualitative and quantitative analyses reported in this study suggest that Scenario 7 or some variation thereof provides the greatest potential for a positive cost–benefit ratio. The most important element in Scenario 7 is the introduction of a test for breakage susceptibility.

A measure of breakage susceptibility accompanied by a price differential in the market would have a far greater effect on levels of BCFM, dust, appearance, and intrinsic quality than changes in factor limits. The use of this measure is currently restricted by lack of satisfactory commercial test technology.

It is recommended that FGIS redirect research efforts to the development of a practical test for breakage susceptibility. A temporary proxy, such as percent of kernels with stress cracks, should be introduced while a range of test technologies are explored and a more objective and automated procedure is developed.

Following are suggested parameters for a breakage susceptibility test, which ***must*** be designed to be usable at country elevators:

1. The breakage susceptibility test should be part of an automated add-on to other tests done at elevators and by FGIS.
2. The test should require no more than one additional minute, start to finish.
3. The test should be fully automated, or it should not require more than one simple operation action (e.g. a weighing to $\pm$ 0.1 g).
4. The test should have a universal moisture correction equation.
5. The precision (repeatability) should be sufficient to group corn in two or three categories, rather than producing a continuous scale value accurate to the three significant figures typical of other grain quality tests.

It is recommended that grades for corn include the following:

1. A test for breakage susceptibility or stress cracked kernels, included as a non-grade standard with reporting required on official certificates.
2. A definition of dockage consisting of CFM separated from the sample by mechanical sieving and reported to the nearest tenth.
3. TBC (material through the 12/64-inch sieve) will be a grade factor, with limits for each grade 1.0 percent less than current limits on BCFM. The lower limits can easily be met with corn that meets the standard for breakage-susceptibility. This change should not be made without first having a breakage-susceptibility test.

The specific definitions of TBC and CFM, including sieve sizes and specifications, should be developed by FGIS in conjunction with a review of current equipment and technology for separating BCFM. The 12/64-inch sieve for TBC and a riddle approximating commercial scalpers for CFM are points of departure for the analysis. Additional considerations are the use of aspirators, single-kernel separators, square-mesh sieves instead of round-hole sieves, different mechanical actions for the sieves, and a combination of mechanical and hand sorting to separate whole kernels.

A final recommendation is that changes in grades should not be introduced or evaluated one factor at a time. The value of grades is a uniform system. It is suggested that FGIS develop a set of ideal grades designed to meet the purposes in the Grain Standards Act. With the ideal set of factor definitions and grade limits available as a final target, FGIS could develop a strategy for moving toward the goal with a minimum of disruption in the industry. Movement toward the ideal will increase the efficiency of communication about value, decrease the costs of marketing, and encourage quality improvement consistent with economic principles.

Endnotes

1. Sizes of all sieves and cleaner screens are given in inches. The conversion from 64th-inch to mm is given below.

Inches	Millimeters
8/64	3.175
10/64	3.969
12/64	4.763
14/64	5.556
16/64	6.350

2. Comments from inland elevators illustrate the concern that a change would be detrimental to the individual firm. Four illustrative comments are reproduced.
   a. Increased costs will have to be absorbed by the country elevator and will not lead to premiums but rather more discounts.
   b. The producer and country elevator will bear the cost of this, and the exporter will reap the benefits.
   c. It would be extremely expensive for the local buyer of grain.
   d. A lot of corn taken in by elevators using the old standard could cost quite a lot of money if that same corn gets graded using the new standard when it is shipped out. Also countries buying 3 grade corn because it is cheaper should not expect No. 1 corn.
3. The base for moisture in corn-export contracts shifted from 15.5 percent to 15.0 percent soon after moisture was removed as a grade-determining factor. When the base for moisture discounts at river elevators changed, discounts by country elevators on farm deliveries changed almost instantly. Most country elevators pass discounts they receive from their buyers on to farmers.
4. The proposal to introduce BC and FM as separate factors on an experimental basis, effective June 30, 1987, identified BC and FM as information on the certificate. The 1986 Grain Quality Improvement Act and the North American Export Grain Association proposal did not define how these factors were to be incorporated into the grades. [*Federal Register*, 52(125):24432, June 30, 1987].
5. Four mail surveys were conducted to obtain data on operating practices and opinions about separating the grade factor BCFM into BC and FM. Four groups were surveyed: export-elevator managers, farmers, buyers of corn screenings, and interior-elevator managers. Their responses are compiled in the table below.
6. Premiums and discounts are relative prices, not absolute values. Changing the number and size of the discounts will almost always be compensated by a

Results of Mail Surveys (Endnote 5)

Survey	Sample size	Number of responses	*Response rate* Percent of sample	Percent of population
Export elevators	98	31	31.6	31.6
Farmers	2,364	2,138	81.2	0.8
Screenings buyers	107	27	25.2	25.2
Interior elevators	1,992	559	28.1	7.7

change in the base price. The best illustration is in a proposal to change the moisture limit for No. 1 soybeans from 13 percent to 14 percent, thus eliminating discounts for 14 percent soybeans. A processor cannot buy water at the same price as soybeans. Because price is determined by the value of the oil and meal produced from each bushel, more water per bushel means less oil and meal per bushel, and the base price must be adjusted accordingly. The same logic holds for adding grade factors, removing grade factors, or changing factor limits. Changes in discounts will be accompanied by changes in base price, so that total value of the crop will be unchanged, but the distribution of the value among farmers delivering different qualities of grain will be changed [Hill, 1982].

7. A review of FGIS export data for 1989 and 1990 shows BC to be approximately 75 percent of BCFM. [See Table 5-4, Meinders and Hurburgh, 1992.]
8. Interior elevators reported that only 7 to 8 percent of inbound receipts were below No. 2 grade on the factor of BCFM. However, average BCFM delivered to country elevators was 1.24 percent in the 1977 study [Hill et al., 1982].
9. In a 1991 survey, 77.1 percent of those surveyed indicated they could reduce FM through improved harvesting practices [Hill and Bender, 1992].
10. Managers of export elevators reported that the primary reason for cleaning corn was to meet the contract specification. Many of the respondents who opposed the proposal to separate BC and FM were worried about an increase in operating costs without any substantial increase in value [Hill et al., 1991b].
11. If the country elevator cleans to exactly 2.5 percent BCFM, the estimated particle size distribution would result in 1.4 percent BC and 0.4 percent FM [calculated from Bern and Hurburgh, 1992, Table 3-4].
12. Changing speed or screen size had little effect on the distribution of particle sizes in the screenings removed[Hill et al., 1991e].
13. Export elevators estimated that installation of a new cleaner or redesigning the cleaning system would cost between $500,000 and $1,500,000 [Hill et al., 1991b].
14. Responses averaged for three states showed 32 percent of farmers in Iowa, Indiana, and Illinois supported separation of BC and FM. Of those favoring a separate factor for FM, 36.9 percent stated a zero percent base was the most effective strategy [Hill et al., 1991c].
15. Of the 109 responses to the question "Can you deliver lower levels of BCFM," 90.8 percent answered yes to at least one of the three choices: by (1) changing production practices, (2) changing harvesting and handling practices, or (3) doing additional cleaning [Hill, 1992].
16. Of the 494 farmers answering the question about the average level of BCFM in corn at harvest, 403 respondents (81.6 percent) stated that they already harvest corn with 2.0 percent or less BCFM, leaving 91 respondents (18.4 percent) who harvest corn containing more than 2.0 percent BCFM [Hill, 1992].

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Glossary

A

Aeration
The passage of air over or through grain to control the adverse effects of excessive moisture, temperature, and humidity. Forced airflow through a grain mass, by reducing temperature and moisture content, improves storability and storage life.

Aspirator
A device that draws a column of high-velocity air across a flowing grain stream to separate low-density materials (foreign material, chaff, insects) from grain. The air pressure is based on the weight of the grain. 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 chaff and insects.

B

BCFM
"Broken corn and foreign material" refers to the current grade factor in corn grades defined as all materials passing through a 12/64th-inch round-hole sieve, plus any non-corn material remaining on top of the sieve.

BC
"Broken Corn" was defined by FGIS in response to the 1986 Grain Quality Improvement Act as all materials passing through a 12/64th-inch round-hole sieve but retained on a 6/64th-inch round-hole sieve.

Base Price
Prices for corn are usually quoted on the basis of No. 2 grade quality in the domestic market. This price quote then becomes a base from which different qualities are determined through discounts.

Blending
The systematic combining of two or more lots or kinds of grains to obtain a uniform mixture of a desired specification.

Breakage Susceptibility
The tendency for corn to break when it is subjected to an impact. The opposite of this test would be resistance to breakage, indicated by the ability of the corn to withstand impact without breaking.

C

CFM
"Coarse foreign material" was defined by FGIS under current standards as all non-corn material retained on top of a 12/64th-inch round-hole sieve hand-picked from the sample. In this study CFM was also used to refer to the material easily removed by mechanical sieving. This definition is comparable to that used for the term *dockage* in other grains.

Cleanliness
The absence of non-grain materials in corn.

Corn By-products
Plant materials originating with the corn, including leaves, cobs, and portions of the kernel that cannot be identified as corn but were derived from some portion of the corn plant.

Corn Loss
The percentage of small, saleable corn kernels that are removed by the cleaner or broken by the motion of the cleaner itself.

Corn Screenings
Material removed from corn by mechanical devices such as vibrating cleaners in the commercial market channel. It consists primarily of broken corn of relatively small particle sizes. In practice, screenings contain a range of particle sizes, from whole kernels to dust. The bulk of the material, however, consists of small particle sizes, as defined under fines.

Country Elevator
A grain-handling facility receiving the majority of its grain directly from farmers.

D

Disc-Cylinder Cleaner
A machine that removes dockage on the basis of particle shape and length. Grain passes through the middle of a horizontal revolving cylinder that has small indentations in the metal. Smaller material falls into the indentations and is lifted as the cylinder revolves. As material approaches the top of the cylinder, the material falls. Depending on the length of the material, it falls into either the dockage compartment or the grains compartment of the cleaner. Disc-cylinder cleaners are generally the most effective means to attain low-dockage levels. However, their throughput capacity is generally less than other types of cleaners.

Discount
A reduction in price used to reflect a difference in the level(s) of grade factor(s) or quality characteristics that differ from a base quality used to establish price level—in other words, a reduction from the base price offered for grain. A discount is generally calculated for factors that lower the value of the grain and may be expressed as a percentage of the price or as fixed cents per bushel. Thus, a discount serves as a disincentive for selling grain below the quality of the base market grade.

Dockage
Non-grain materials that can readily be removed by accepted mechanical screening devices. The technical definition of dockage in official grades differs among grains, but in general it refers to material readily removed during screening.

Dry Milling

A corn-processing technology in which the kernel is separated into its component parts primarily through mechanical means. Primary products are corn grits, corn flour, and corn germ.

E

Economic-Engineering Study

A research approach for assessing the relationships between costs and output for a production process by separating the production process into discrete stages and assigning costs to the input–output relationship.

Economic-Engineering Model

A model for calculating costs based on technical coefficients multiplied by market prices of each input. In this study it refers to the cost of operating grain cleaners, and under assumed conditions it calculates the cost for different volumes handled. The method is in contrast to conducting surveys in which respondents are asked to report their actual or estimated costs.

Export Elevator

A grain-handling facility located at a port whose primary responsibility is assembling grain from different regions, blending it to contract specifications, and loading it on ocean vessels for export.

F

FGIS/USDA

The Federal Grain Inspection Service of the U.S. Department of Agriculture, the agency created by 1977 legislation, is charged with the responsibility for administering the U.S. Grain Standards Act.

FM

"Foreign material" was defined by FGIS in response to the 1986 Grain Quality Improvement Act as all materials passing through the 6/64th-inch round-hole sieve, plus non-corn material retained on the 12/64th-inch round-hole sieve.

Factor Limits

The maximum or minimum value for each characteristic for each grade is specified in USDA grades. In this study, proposed scenarios introduce new factors and alternative limits for those factors that will force samples to be placed in different grades.

Fines

Finely broken material passing through a sieve. The size of the sieve varies with the particular reference, but in general the term refers to material smaller than 8/64th-inch.

Fumigation

The destruction of pests infesting grain by professional personnel, trained in the application of fumigants (chemicals that at required temperature and pressure can exist in a gaseous state in sufficient strength and quantities to be lethal to a given pest). Fumigants are some of the most toxic and unique pesticides. Methyl bromide and hydrogen phosphide are the fumigants most commonly used on grain.

G

Grade

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

Grade-Determining Factors

The attributes whose limits designate a numerical grade, such as damage and broken corn and foreign material.

Grain Grades and Standards

Specific standards of grain quality established to maintain uniformity of grains from different lots. Grades and standards permit the purchase of grain without the need for visual inspection and testing by the buyer.

I

Inland Sub-terminal Elevator

A grain-handling facility receiving the majority of its grain from other country elevators. These facilities assemble sufficiently large grain lots to take advantage of low-cost, large-volume transport by rail.

Intrinsic Value

The value of the raw grain that is inherent within the kernel. It is measured in terms of the quantity and quality of products that it will yield; generally based upon its value in processing for food, feed, or industrial products.

L

Low-temperature Drying

Drying technologies in which the temperature of the air forced through the corn mass is increased by no more than 5°C above ambient air.

M

Macro Approach (Aggregate Approach)

A model that examines costs and benefits within the context of the total industry using the assumptions that changes in volume, quality, and prices will be reflected throughout the market channel in proportion to the total magnitude of the change.

Micro Approach

A model that examines costs and benefits as viewed by an individual firm. In general the more widely distributed effects of all firms following the same strategy are ignored, and the individual firm looks at current price–cost relationships on the assumption that the firm's actions will not alter these market relationships.

N

NAEGA

The North American Export Grain Association is an association whose members are primarily involved in exporting grain.

Non-grade-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. An example: moisture.

P

Premium
An upward adjustment in price per bushel to reflect difference(s) in quality above the base quality used to establish price level; in other words, increases from the base price offered for grain of higher quality characteristics than specified. Generally, premiums are calculated for factors that increase the value of the grain.

Protectant
An insecticide used to apply to or mix with grain to protect the grain from insect infestation.

R

River Sub-terminals
Grain-handling facilities with access to barge loading points, receiving grain from both farmers and country elevators.

S

Screen Cleaner
A series of angled, perforated plates or wire screens that separate the grain from particles that are larger than the grain. The screens may be stationary or they may be shaken or rotated. Screen cleaners remove dockage or foreign material on the basis of particle size. The screens may differ. Smaller openings remove less dockage, but they also reduce throughput capacity. Generally, however, screen cleaners are used to remove large particles.

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

Shrink
The reduction in weight of corn as the result of moisture loss, biological activity, and respiration within a corn mass. Shrink is primarily the result of changes in moisture content but may also be caused by reduction in dry matter as a result of biological activity.

Spout Line
The line of grain as it is dropped into a container (bin or ocean vessel). Fines in the grain tend to stay where they fall, but whole kernels tend to roll to the outside. The result is an area directly under the filling spout that consists primarily of fine materials through which it is difficult to move air and that is more susceptible to damage from insects and mold.

Storability
The inherent characteristics and handling and storing history of a lot of corn that determine its storage life. The greater the storability, the longer will be the storage life, the time span during which the corn can be stored before deterioration takes place.

Stress Cracks

Internal fissures or cracks within the corn kernel that increase the susceptibility of the corn to breakage during subsequent handling. Stress cracks are caused by rapid changes in temperature or moisture content within the corn kernel or by other internal stresses, causing a break within the endosperm that does not carry all the way out to the pericarp.

T

Test Weight

A measure of grain density based on the weight of one bushel determined by volume (1.125 cubic feet). The overall weight is determined by weighing the quantity of grain. The term *test weight* was used from the early beginnings of corn grades and is related to density, but it is also influenced by many other factors.

V

Value in Use

The value of corn in the market channel is determined in part by the value of the products that can be derived from it. The value of final products is generally reflected back through the market channel with appropriate subtractions for competitive costs and margins and thereby influences the price of the raw corn.

W

Wet Milling

A corn-processing technology involving some degree of steeping in order to separate corn into its various chemical constituents. Primary products are starch, sugar, alcohol, and oil.

Appendix: Using Grades to Enhance Competitiveness

In the longer run, U.S. market share can be increased only if other countries reduce their exports. Major shifts in resource use will be made only in response to changes in profitability of corn production relative to other crops. A review of past changes in world supply shows that an increase in world prices has usually been followed by an increase in production of corn from exporting countries. The response to ***decreased*** prices has not been symmetrical with response to ***increased*** prices. Small increases in world prices have encouraged expansion of production and exports—small decreases have not decreased supply, but only slowed the expansion. With the exception of the United States, most production above domestic needs must enter the export market—few countries outside the United States provide long-term storage of surplus production. Therefore, changes in corn production in Argentina, Thailand, China, and South Africa are usually accompanied by similar changes in export volume. The magnitude of changes in world prices due to quality is much smaller than price changes caused by variations in supply and demand. Since price swings as large as 50 cents per bushel have not deterred production of corn in Argentina, it can be assumed that changes in value due to lower limits on BC or FM will not alter corn production in Argentina.

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NC-151 Administrative Advisor

James H. Brown
The Ohio State University
Ohio Agricultural Research and Development Center
1680 Madison Avenue, Wooster, OH 44691-4096

NC-151 Technical Committee

Requests:

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