Chapter 4

Quality Attributes Important to Domestic and Overseas Industries

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Grain quality, or more importantly the attributes that constitute it, is as varied as the number of grains and commercial processes used to produce finished products. Quality attributes can vary from perfect kernels used for seed to highly damaged corn kernels used in fuel production, and may entail cleanliness, health, and safety concerns, Add to this cultural differences and consumer preferences, and what may be considered high quality for one use may be considered poor quality for the next.

Other than concerns for conditions affecting sanitary quality, no one set of physical or intrinsic characteristics fully describes quality for any one particular grain. Physical and chemical differences exist between varieties as a result of heredity, soil, and climatic conditions. Further, in the case of wheat, intrinsic quality characteristics vary from one type to the next. Even in the case of flour, however, the way the flour will ultimately be used has an impact on the intrinsic wheat attributes required for high quality.

Quality attributes (sanitary, physical, and intrinsic) are measured using a multitude of specific tests designed to provide information on the various characteristics of grain. The most commonly used tests for sanitary and physical quality are those contained in the Official United States Standards for Grain, These include measurements for conditions such as kernel density; moisture; damaged, broken, or split kernels; impurities; and other visual defects, In addition to tests provided for in the grain standards, each industry, along with individual companies within each industry, has either developed or uses internationally accepted testing procedures. These determine values for intrinsic characteristics that ultimately influence decisions on the grain's suitability for a particular process and product. Even the use of any one of these tests varies by industry and is influenced by the type of product produced. Beyond tests for quality attributes, uniform or consistent quality within and between shipments can also influence buyers' perceptions of quality, The ultimate test for quality is how well the grain performs in actual use.

As processing technologies, increased numbers of uses, and more sophisticated methods of using grain become available, specialization in specific quality attributes becomes more critical. This is especially true in the case of wheat. Flour quality is more narrowly defined for milling than for baking because milling is more standardized around the world, even though it varies by level of development within a country. A multitude of baking technologies exists that are becoming more sophisticated, thus requiring flour quality to be more closely regulated. This places increased importance on the attributes required of wheat, in addition to their consistency within and between shipments.

Since what constitutes physical and intrinsic quality varies according to processor (wheat miller, corn dry and wet miller, soybean processor, and feed manufacturer), the important attributes of each were examined for this assessment. OTA identified the quality attributes important to each industry as they relate to either the attribute itself or the test used to measure the attribute. The important attributes are outlined later in this chapter, The levels at which these attributes affect the quality of a finished product are not discussed since the values placed on the attribute by an individual industry have an impact on ideal quality, For example, protein quantity and gluten strength are important attributes in wheat. However, high protein and strong gluten are required by millers to produce a high-protein, strong flour for bread, whereas low-protein and weak gluten are required for low protein, weak flour used to produce cakes and pastries, To aid further in this evaluation, surveys of domestic and overseas processors were conducted to identify the important attributes and/or tests.

SURVEY DESCRIPTION

OTA developed questionnaires for each domestic industry. The 1987 Milling Directory was used to identify wheat milling and corn dry and wet milling companies. Additional input was provided by their trade associations. Questionnaires then were sent to 119 wheat millers, 64 corn dry millers, and 6 corn wet millers—all the companies in each industry. Since there are thousands of feed manufacturers in the United States, the American Feed Manufacturers Association assisted in identifying 190 major companies to be surveyed. The Soybean Processing Directory, along with help from the National Soybean Processor Association, was used to identify 19 major soybean processing companies.

Responses were received from 57 out of 117 wheat milling companies (48 percent), 24 out of 64 corn dry milling companies (38 percent), 4 out of 6 corn wet milling companies (75 percent), 83 out of 190 feed manufacturing companies (44 percent), and 10 out of 19 soybean processing companies (53 percent).

An overseas wheat questionnaire was also developed by OTA and administered in 18 importing countries (table 4-I) by the U.S. Wheat Associates. All but one country responded. Corn and soybean overseas questionnaires were not developed since work was already being done in this area by other research groups, which provided data to OTA for use in this analysis.

In order to gather information on the importance of the specific attributes and/or tests identified, five basic areas were examined:

1. the attribute's and/or test's importance,
2. how the attribute and/or testis used when purchasing grain,
3. whether quality has decreased as evidenced by any of the tests,
4. whether grain standards adequately reflect conditions important to their operations and if more tests are needed, and
5. the test's importance as it pertains to uniformity between shipments.

Table 4-1.—Countries Included in OTA Wheat Survey, by Region

Far East	***Europe***
China	Soviet Union
Japan	Norway
Indonesia	The Netherlands
Taiwan	Italy
Republic of Korea	France
Philippines	United Kingdom
Middle East	Switzerland
Egypt	
India	
South America	
Venezuela	
Brazil	
Chile	

SOURCE: Office of Technology Assessment, 1989,

Respondents were asked in several questions to rank each attribute and/or test using a scale of 1 to 7. Four was defined as being neither important nor unimportant, 5 as slightly important, 6 as moderately important, and 7 as extremely important. Yes and no questions were also used and respondents were asked to identify the attributes and/or tests of particular concern when answering yes. The information collected in this survey only represents the respondents' concerns at the time it was administered, a point worth noting given the fluctuations in perceptions about important quality issues in these industries.

QUALITY MEASUREMENT AS EVIDENCED BY OFFICIAL STANDARDS

Official grain standards developed for wheat, corn, and soybeans establish certain factors used to describe a level of quality and provide a basis for marketing grain. (The need for grain standards and the ways they are implemented are discussed in ch. 8.) Each standard covers areas such as grain type; bulk density; degree of cleanliness; amounts of broken, shriveled,

or split grains; moisture content; amounts of impurities including damaged kernels; and other areas relating to the sanitary and physical condition of grain. The levels for each factor used to define a grade, as well as their impact on the finished product, have caused considerable debate regarding the usefulness of the factors and the limits established by the grades themselves. This assessment does not address the specific limits used to define grades, but merely focuses on the factor's importance.

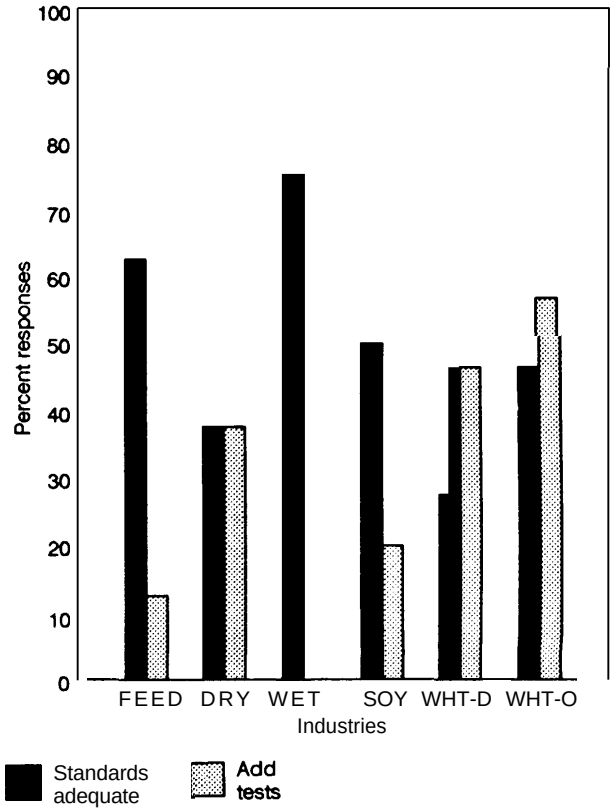
Much research has been done on determining the impact that physical properties such as type, color, kernel hardness and size, and degree of kernel damage have on various products. For example, kernel damage resulting from heating, storage and field fungi, frost, and immaturity have been shown to affect flour and oil quality. Factors such as excessive moisture content, the presence of molds or mycotoxins, the amount of material other than grain, live insects, and rodent excreta are not desired in any product.

All industries desire grain with good bulk density and safe moisture levels that is clean and free from impurities and otherwise fit for processing. These factors in various ways are covered by the grain standards. Domestic industries as well as overseas wheat millers were asked if the factors contained in the standards adequately reflect conditions important to their operation and whether additional tests are needed (figure 4-I).

For the three corn industries (wet millers, dry millers, and feed manufacturers), the degree to which the factors contained in the corn standard reflects conditions important to their operations varies; only the dry millers see a need for additional tests. Only half the domestic soybean processors considered the soybean standard adequate, but few respondents indicated the need for additional tests.

Domestic wheat millers generally felt the wheat standard does not adequately reflect conditions important to their operations. The need for additional tests is evident from responses from domestic and overseas respondents, but is slightly higher for overseas millers even though they consider the wheat standards more adequate. This section discusses each grain standard along with information gathered from the survey on the importance of the specific factors covered by each standard.

Figure 4-1. -Adequacy of Grain Standards



ABBREVIATIONS:
FEED = Feed manufacturers
DRY = Dry millers
WET = Wet millers
SOY = Soybean processors
WHT-D = Wheat millers (domestic)
WHT-O = Wheat millers (overseas)

SOURCE: Office of Technology Assessment, 19S9

Wheat Standard

Wheat is grouped according to growing habit, color, and kernel texture. The major distinction, however, is its growing season. Winter wheats are planted in the fall and harvested in the summer; spring wheats are planted in the spring and harvested in the fall. Both winter and spring wheats produce grain that is red, white, or yellowish amber in color. Wheat is

also grouped according to whether it is hard or soft. Spring and winter types tend to be higher in protein and are principally used in bread flour, Softer wheats, white and red types, contain lower protein and are milled into flour for cakes, cookies, pastries, and crackers. Durum wheat, which is very hard, is milled into semolina for pasta products (9). These general groupings have resulted in the establishment of seven basic classes: Hard Red Spring, Hard Red Winter, Soft Red Winter, White, Durum, Unclassed, and Mixed.

The wheat standard, in addition to establishing classes based on the above criteria using visual examination, provides information on:

- test weight,
- moisture,
- heat-damaged kernels,
- damaged kernels total,
- foreign material,
- shrunken and broken kernels,
- total defects,
- contrasting classes, and
- wheat of other classes.

Also measured are the number of live insects; the amount of dockage (material other than wheat that can be removed by scalping, aspiration, and screens); special conditions such as the presence of garlic and ergot; and the amount of stones, metal, glass, and toxic weed seeds.

Respondents were asked in the domestic survey to rank the importance of each factor as it pertains to producing four major flour types: hard wheat flour, whole wheat flour, soft wheat flour, and semolina. In addition to evaluating whether flour type has a bearing on a factor's importance, the company's daily production capacity was also factored in. The cutoff point for capacity was set at 5,600 daily hundred weight (cwt) capacity. The number of responses in the 5,600-cwt-and-over range accounted for approximately 83 percent of the total U.S. daily milling capacity.

All factors currently contained in the wheat standard were ranked as 5 (slightly important) or higher by domestic millers, Each factor's importance was similar across flour types and milling capacities, with the highest ranking being for live insects. Overseas millers also ranked all factors as 5 or higher. They were slightly less concerned than domestic millers about live insects, contrasting classes, and wheat of other classes. For the remaining factors, overseas millers generally regarded the factors as being slightly more important, especially in the case of dockage (figure 4-2).

Information was collected on whether the wheat standard is used when purchasing wheat and if contracts are based on grade only, grade and factor, or only factors (figure 4-3). Even though specific factors included in contracts vary, 79 percent of the domestic respondents indicated they use the wheat standard and include limits for one or more of the factors in their contracts. This compares with 34 percent for overseas respondents, Significant differences were found between milling capacities for domestic respondents regarding using the wheat standard for contracting, Those with 5,600 cwt and over capacity indicated that limits for some or all factors are always included in contracts,

Corn Standard

Corn is classed based on color without regard to growing habit. With color serving as the basis for classing, three classes have been established: Yellow, White, and Mixed. In addition to visually classing based on color, the corn standard provides information on:

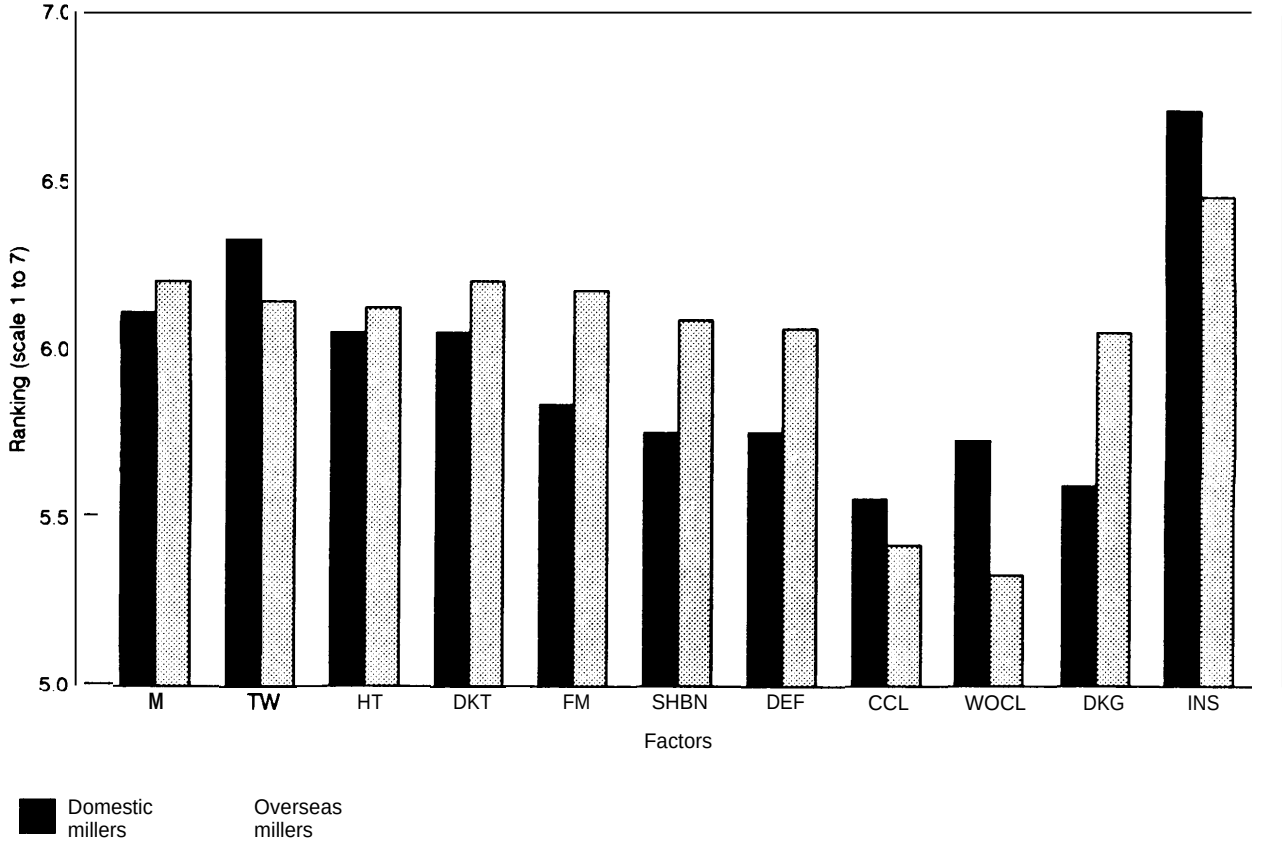
- test weight,
- moisture,
- heat-damaged kernels,
- damaged kernels total, and
- broken corn and foreign material,

The number of live insects, along with stones and toxic weeds, are also included,

Unlike the wheat standard, the corn standard is used by several different industries, Therefore, domestic questionnaires where sent to dry millers, wet millers, and feed manufacturers,

All industries ranked the factors as 5 (slightly important) or higher except for class in the wet

Figure 4-2.-importance of Wheat Standard Factors



ABBREVIATIONS:

M = Moisture	FM = Foreign material	WOCL = Wheat of other classes
TW = Test weight	SHBN = Shrunken and broken kernels	DKG = Dockage
HT = Heat damage	DEF = Total defects	INS = Live insects
DKT = Damaged kernels (total)	CCL = Contrasting classes	

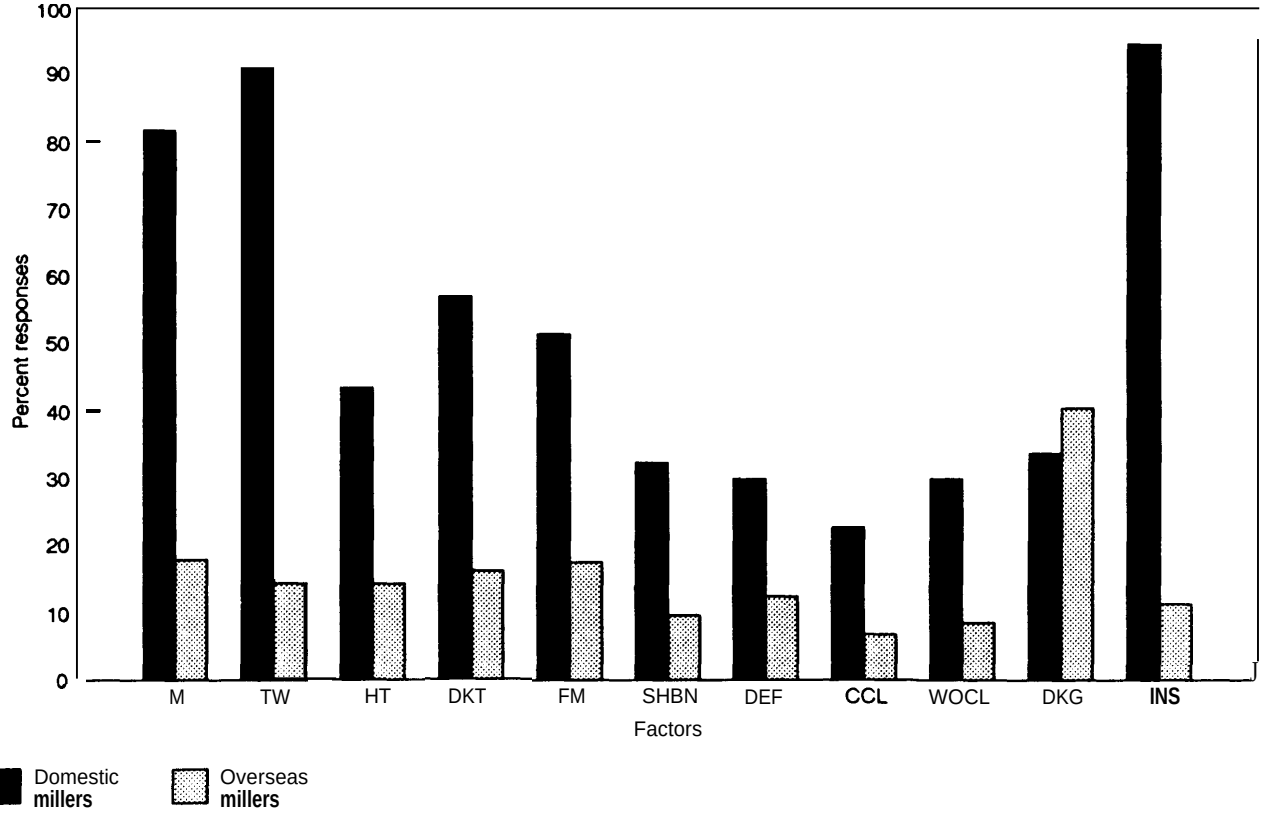
SOURCE. Office of Technology Assessment, 1989

milling and feed manufacturer responses (figure 4-4), Differences exist across all industries regarding the importance of certain factors, but wet millers consistently ranked factors as more important than the other two,

Industries differ on which factors have limits included in contracts. All wet millers indicated they use the corn standard and include limits in their contracts for one or more of the factors. This compares with 75 percent for the dry milling and feed manufacturers. Except for broken corn and foreign material, the frequency with which individual factors are included in contracts varies (figure 4-5), Moisture was mentioned the most often by feed manufacturers, whereas heat-damaged kernels was contracted for the most often by dry millers and damaged kernels total was included by wet millers.

The data on the importance to overseas industries of factors contained in the corn standard were obtained from surveys not conducted by OTA. This resulted in only one common area—contracting—between the OTA domestic questionnaire and overseas responses. Responses by the three overseas industries indicated that limits for moisture, test weight, damaged kernels total, and broken corn and foreign material are included in contracts by

Figure 4-3. - Use of Wheat Standard Factors in Contracts.



ABBREVIATIONS:

M= Moisture
TW = Test weight
HT = Heat damage
DKT = Damaged kernels (total)
FM = Foreign material
SHBN = Shrunken and broken kernels
DEF = Total defects
CCL = Contrasting classes
WOCL = Wheat of other classes
DKG = Dockage
INS = Live insects

a Percentages are based on number of responses that use standards for contracting

SOURCE. Office of Technology Assessment, 1989

wet millers and feed manufacturers. Moisture, damaged kernels total, and live insects are included in contracts by dry millers.

Soybean Standard

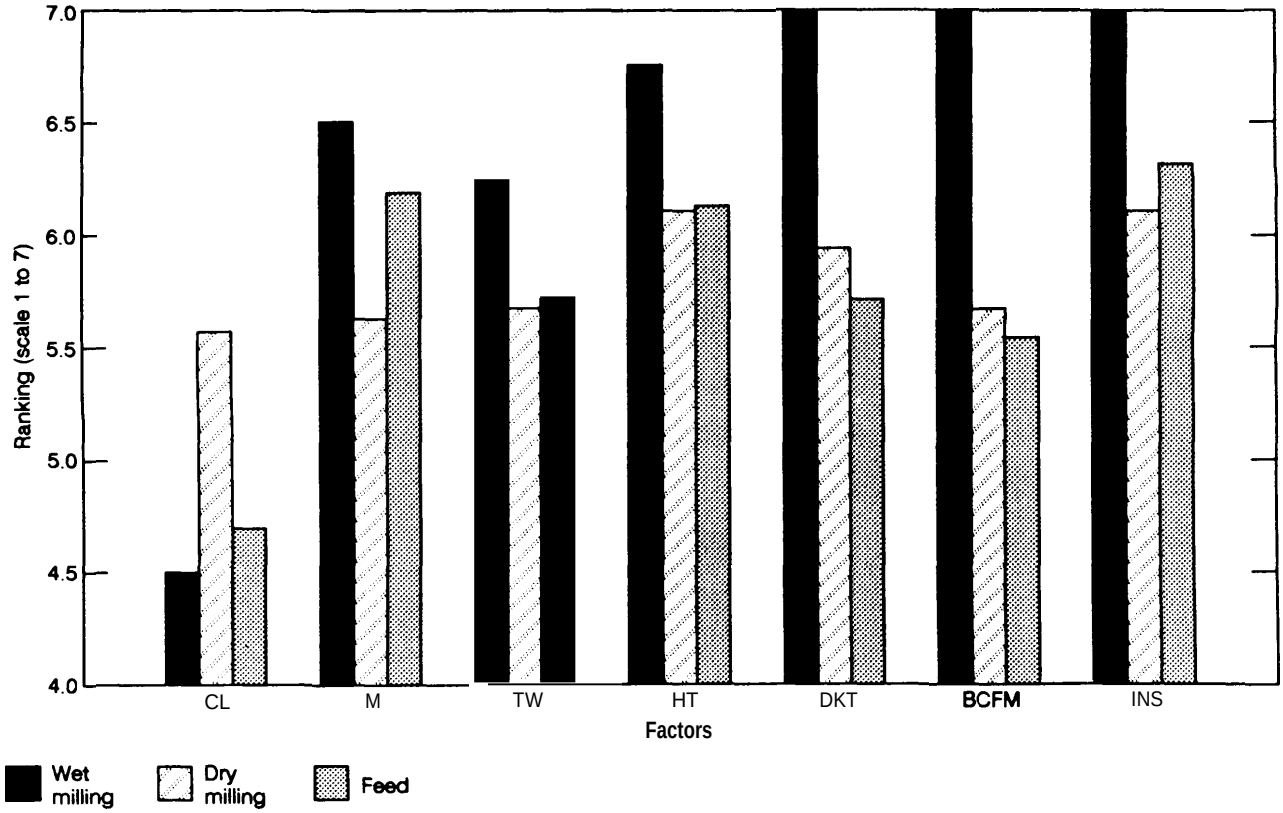
Soybeans are classed based on color, and two classes have been established: Yellow and Mixed. In addition to visually classing based on color, the soybean standard provides information on:

- test weight,
- moisture,
- heat-damaged kernels,
- damaged kernels total,
- foreign material, and
- splits.

The number of live insects, garlic, stones, and toxic weeds are also included.

Several factors were ranked below 5 (slightly important) by domestic soybean processors class, test weight, and splits (figure 4-6), The test for live insects did not rank as the most important test, as it did for wheat and corn, since live insects are not normally a problem in soybeans. Heat-damaged kernels received the highest ranking for soybeans.

Figure 4-4.--Importance of Corn Standard Factors



ABBREVIATIONS:

CL = Class
M = Moisture
TW = Test weight
HT = Heat damage
DKT = Damaged kernels (total)
BCFM = Broken corn and foreign material
INS = Live insects

SOURCE: Office of Technology Assessment, 1989

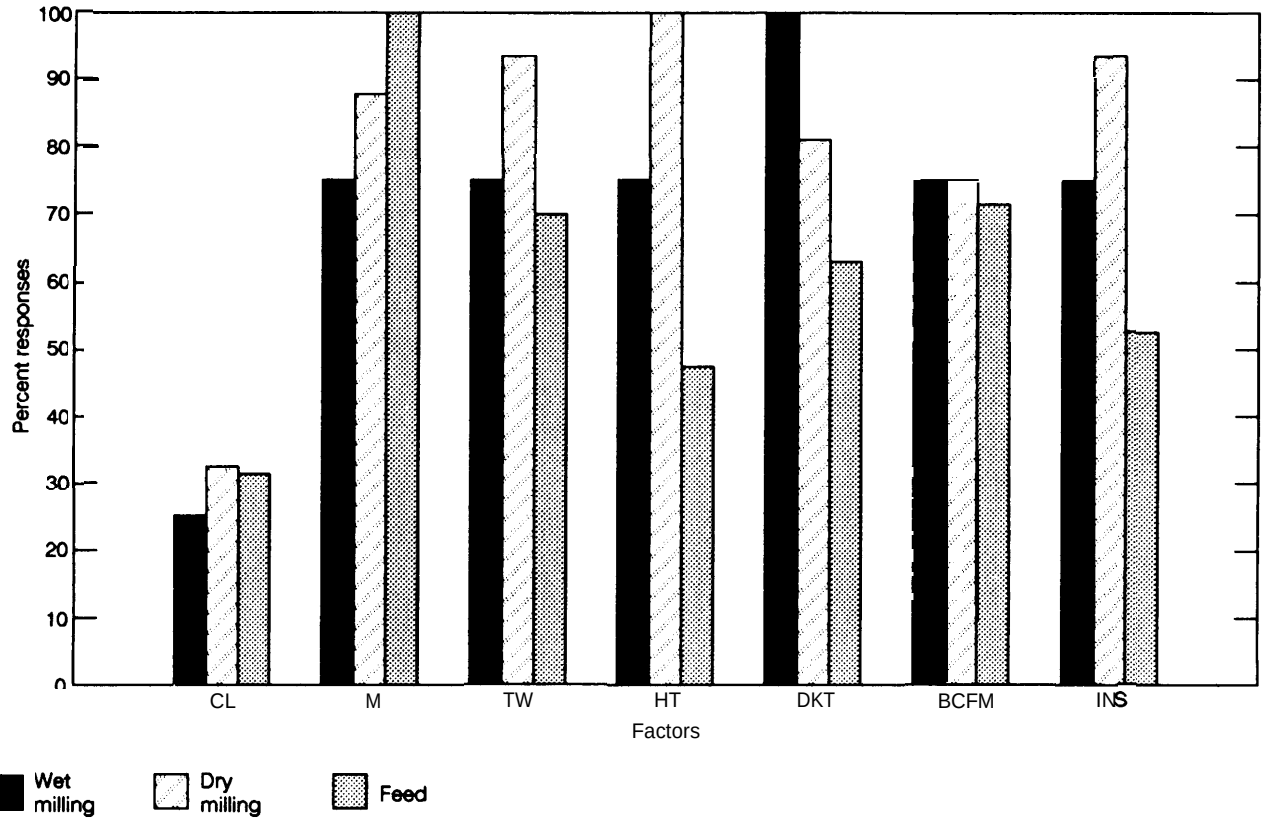
All soybean processors indicate that they use the soybean standard and set limits in their contracts for one or more factors. Moisture and heat-damaged kernels were identified as being contracted for the most often (figure 4-7).

As with the corn standard, information on the importance to importers of factors contained in the soybean standard was obtained from another survey. Moisture and foreign material were ranked as most important by overseas soybean processors, while moisture, test weight, and damaged kernels total were identified as having limits included in contracts.

IMPORTANT ATTRIBUTES FOR WHEAT, CORN, AND SOYBEANS

Many factors influence grain value and what is considered quality either by affecting wholesomeness or by affecting the yield and quality of the finished product. Factors such as pesticide residue, molds, mycotoxins, toxic weed seeds, insect fragments, and soon affect a product's wholesomeness. Yield and quality can be affected by variety; kernel size, shape, color, and hardness; foreign material, dust, and stems; and intrinsic properties such as protein, oil, and

Figure 4-5. -Use of Corn Standard Factors in Contracts •



ABBREVIATIONS:

CL = Class
M = Moisture
TW = Test weight
HT = Heat damage
DKT = Damaged kernels (total)
BCFM = Broken corn and foreign material
INS = Live insects

a percentage are based on number of responses that use standards for contracting

SOURCE: Office of Technology Assessment, 1989

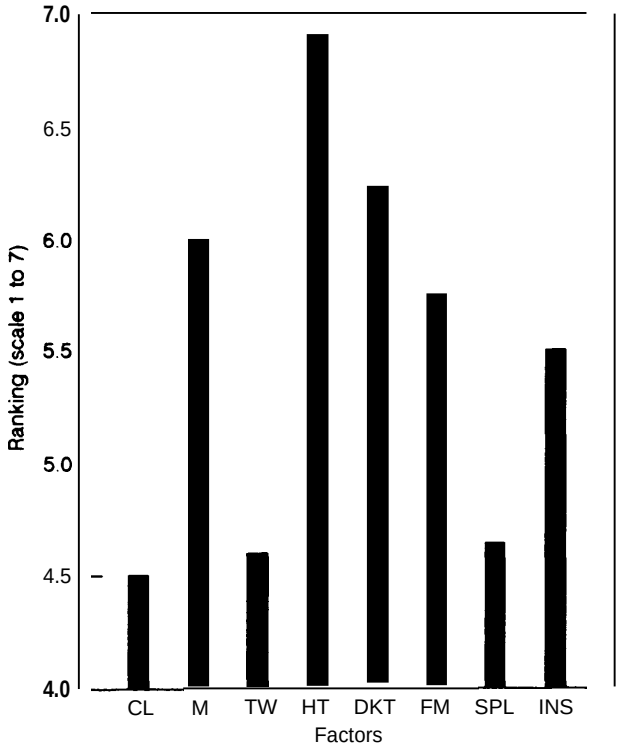
starch. This section examines wheat, corn, and soybeans for these type of factors.

Wheat

The ultimate test for wheat quality is whether it will bake an acceptable product. Protein quantity and quality, the amount of alpha amylase, and dough handling properties (water absorption, mixing time, and extensibility) along with other tests are used as indicators of quality and impact on baking quality. Except for Durum, the differences between the amount of protein required to produce certain products and the range of protein between classes reveal the inability of any one wheat class to be perfectly suited-for any one finished product (figure 4-8). This is also true for wheats produced in various regions of the world. This forces millers to blend different wheat types in order to produce the flour quality desired. Not only can different types be blended, but importers blend different U.S. wheat classes with wheats imported from other countries (table 4-2).

Millers blend wheats in order to produce flour that can meet the variety of demands of various finished products. In many instances flour produced from the various flour streams

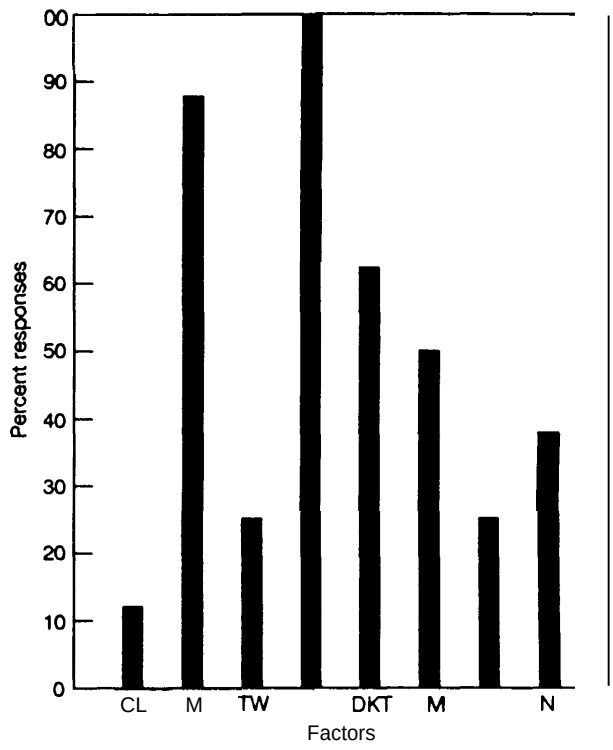
Figure 4-6. - Importance of Soybean Standard Factors



ABBREVIATIONS:
CL = Class
M = Moisture
TW = Test weight
HT = Heat damage
DKT = Damaged kernels (total)
FM = Foreign material
SPL = Splits
INS = Live insects

SOURCE: Office of Technology Assessment, 1989

Figure 4-7.-Use of Soybean Standard Factors in Contracts[a]



ABBREVIATIONS:
CL = Class
M = Moisture
TW = Test weight
HT = Heat damage
DKT = Damaged kernels (total)
FM = Foreign material
SPL = Splits
INS = Live insects

a Percentages are based on number of responses that use standards for contracting

SOURCE: Office of Technology Assessment, 1989

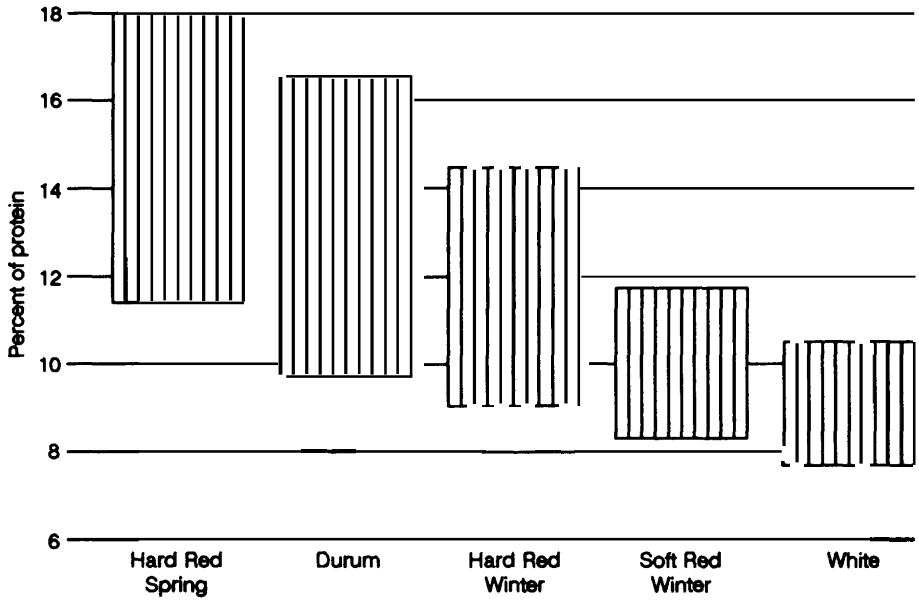
(see ch. 3) is also blended to meet the specific quality demands placed on flour. Information on protein quantity and quality along with other important quality characteristics such as the amount of alpha amylase (as measured by the falling number test), dough handling properties (as measured by farinograph, mixograph, extensograph, and alveograph tests), and bake test results are all used to determine the quantities of each wheat type that will go into the blend.

To produce a hearth bread, spring and winter/spring mixes maybe required. Spring, winter/spring mixes, and winter wheats are used for buns and rolls. Pan bread uses winter, winter/spring mixes, and spring wheat. Cakes and pastries may use red and white soft wheat, low-protein winter, and blends of other wheat types. In addition, U.S. winter wheats with various attributes from various regions may be blended with spring wheats. Blending wheats from various origins, types, and intrinsic characteristics allows millers to produce flour to meet various flour specifications, maximize the milling operation, and produce uniform, consistent flour quality.

To illustrate this point further, the OTA overseas questionnaire collected information on the primary reason for importing wheat. Five basic reasons were suggested:

1. to supplement the volume of domestic wheat,

Figure 4-8.-Protein Range and Flour Uses of Major Wheat Classes



Flour uses

- Used to blend with **weaker wheats for bread flour**
- **Whole wheat bread, hearth breads**
- Egg noodles (U.S.), macaroni, **and other alimentary pastes**
- **White bakers' bread, bakers' rolls**
- **Waffles, muffins, quick yeast breads, all-purpose flour**
- **Noodles (Oriental), kitchen cakes and crackers, pie crust, doughnuts and cookies, foam cakes, very rich layer cakes**

NOTE: Flour uses are approximate level of protein required for specified wheat products. Durum is not traded on basis of protein content.

SOURCE: U S Department of Agriculture, Economic Research Service, Wheat Background for 1985 Farm Legislation," Agricultural Information Bulletin No 4S7, September 19S4

Table 4-2.—Regional Tastes and Preferences for Wheat= Based End Products and Their Requirements

Region	Major products consumed	Averaged required protein level (in percent)	Types of wheat used
Fast East Asia	Pan bread	12-14	Hard red
	Steamed products	10-11	Medium-hard
	Noodles	9-11.5	Medium-hard white
	Chappatis	9-1o	Soft to medium-hard white
Middle East and North Africa	Bread		Durum, medium-hard white and red
	Couscous, pasta, bulgur, fereek	9-11	Durum
Europe	White pan bread	10-12	Hard red, domestic soft
	Rolls	9.5	
	Pasta		Durum
Latin America	Breads	10-14	Hard red, domestic soft
	Pasta		Durum

SOURCE: Canada Grains Council, *Wheats of the World* (Winnipeg, MB, 1979).

to supplement quality for blending with domestic wheat,
equalities are not available in domestic wheat,
as feed, and
local wheat is not available.

As more than one reason may apply to a particular country, respondents were asked to indicate all that applied, The results indicate that 51 percent import wheat to supplement volume, 32 percent to supplement quality, 47 percent because quality is not available in domestic

wheat, 6 percent for feed, and 13 percent because local wheat is not available.

Importers' preferences for bread, soft, and Durum wheats from all countries exporting these types were also evaluated. Each respondent was asked to rank their preference assuming that price, transportation, and other related costs were equal. Overall the United States did not rank as first choice, even though some respondents did identify it as first choice, The average for all responses is shown in table 4-3.

When identifying important wheat attributes, the demands placed on flour quality must be considered. Flour is used to produce a large number of products under various baking conditions. Advances in milling technology have enabled millers to increase the water absorption of flour so bread yield can be increased. Flour protein levels can also be modified by air classification. This process separates low-protein flour for use in cakes and pastries from high-protein flour that can be used to blend with other flours (2). In addition to traditional leavened bread, many countries produce a variety of unleavened products using weaker flour and chemical leavening.

Flour is classified according to strength, ranging from strong to weak (7). Strong flours have relatively high protein and elastic gluten and can be baked into loaves that have good crumb, grain, and texture. They require considerable water to make a dough that produces a high-yield bread. Doughs from strong flours have excellent handling properties. They are not critical in their mixing and fermentation properties, and yield good bread over a wide range of baking conditions.

Weak flour, on the other hand, has relatively low protein, weak gluten, and low water absorption; it yields dough of inferior handling quality for bread baking, and mixing and fermentation requirements are critical. Weak flours, therefore, require less mixing and fermentation than strong flours and can be used to bake biscuits, crackers, and pastry. Intermediate flour strengths can be considered all-purpose flours for use in traditional household applications.

Baking technologies also influence flour attributes, Chemical and mechanical dough development processes require lower flour protein and weaker gluten than straight (traditional) dough processes. Since flour can be used for home use, in small bakeries, and in highly mechanized plants, knowledge of intrinsic wheat attributes along with how the flour will be baked are required in order to produce a quality flour.

Since no one set of values—high v. low protein or strong v. weak flour-meets the needs of all products, the survey questionnaire was used to determine which attributes and/or tests are important to wheat millers here and abroad, No effort was made to determine levels since they vary by product, country, and baking technology.

Traditionally, wheat class has been used as a quality indicator. Spring wheats have traditionally been high-protein, strong gluten wheats used to make products requiring strong flours and for blending with other wheat types. Soft wheats, which are lower in protein, are used in products requiring weak flour. Domestic and overseas millers were asked if "wheat class is

Table 4"3.—Importers Preference for Wheat by Type and Source

Bread-type wheats	Soft-type wheats	Durum wheats
1. Canadian spring	1. Australian standard white	1. Canadian
2. Australian prime hard	2. U.S. white	2. Us.
3. U.S. spring	3. U.S. soft red	3. Argentinean
4. U.S. hard red winter	4. Australian soft white	4. EC
5. Australian hard	5. EC soft	
6. Argentinean hard		
7. EC soft		
8. U.S. soft red		

SOURCE OTA Overseas Wheat Survey, 1988

a good indicator of wheat quality"; both groups indicated that wheat class alone is not a satisfactory indicator of quality.

In an effort to identify the importance of various attributes and/or tests to domestic millers, the survey listed 28 attributes and/or tests not currently found in the wheat standard. As in the wheat standard analysis, the 28 items were evaluated by flour type and an analysis was made between capacities for domestic millers.

Other than attributes and/or tests not normally used for a particular flour type, no significant differences were found between flour types. Slightly more variability between flour types was evident in the under-5,600-cwt category, and overall rankings varied on some items between capacities (figure 4-9). Eight items (protein, mycotoxins, alpha amylase, falling number, pesticide residue, hidden/dead insects, flour protein, and bake test) were ranked as 6 (moderately important) by the over-5,600-cwt capacity companies. Only mycotoxins, pesticide residue, and hidden/dead insects were ranked as 6 or higher by the smaller companies.

In the overseas questionnaire, only 22 attributes and/or tests were included. Most respondents did not rank the items using the 1 to 7 scale but merely checked the important ones. The importance ranking is therefore based on the frequency with which they responded.

Significant differences exist between items, but more importantly between regions of the world (figure 4-10). For example, protein and alpha amylase were considered the most important by Far East countries. This compares with protein, the falling number test, starch damage, and flour yield in the European Community (EC). Overall, the Far Eastern countries ranked the majority of the items as more important, followed by EC, South America, and then the Middle East.

The frequency with which the 28 items were included in domestic contracts was also examined. Overall, 70 percent of those responding (but 88 percent of the 5,600-cwt-and over category) indicated that one or more items were included in contracts. Five items (protein, hidden/dead insects, pesticide residue, falling number, and farinograph) were identified as being contracted for most frequently.

Only 14 of the 22 attributes and/or tests listed in the overseas questionnaire are included in contracts. Sixty-two percent of those responding indicated that protein is specified in each contract. Of the remaining 13 items, 23 percent indicated they specify limits for one or more. The falling number test and radiation ranked first (45 percent) followed by the farinograph test (36 percent), pesticide residue (18 percent), and mycotoxins (18 percent).

Both groups indicated additional tests are needed, as demonstrated by their responses on whether the wheat standard adequately addresses their needs. The falling number test and pesticide residue were the main items identified by both groups (figure 4-11). Domestic millers also marked hidden/dead insects for inclusion. Overseas millers identified tests for dough handling properties (farinograph, extensograph, alveograph, and amylograph) for inclusion, while domestic millers did not indicate any preference for these tests even though they often contract for the farinograph.

Corn

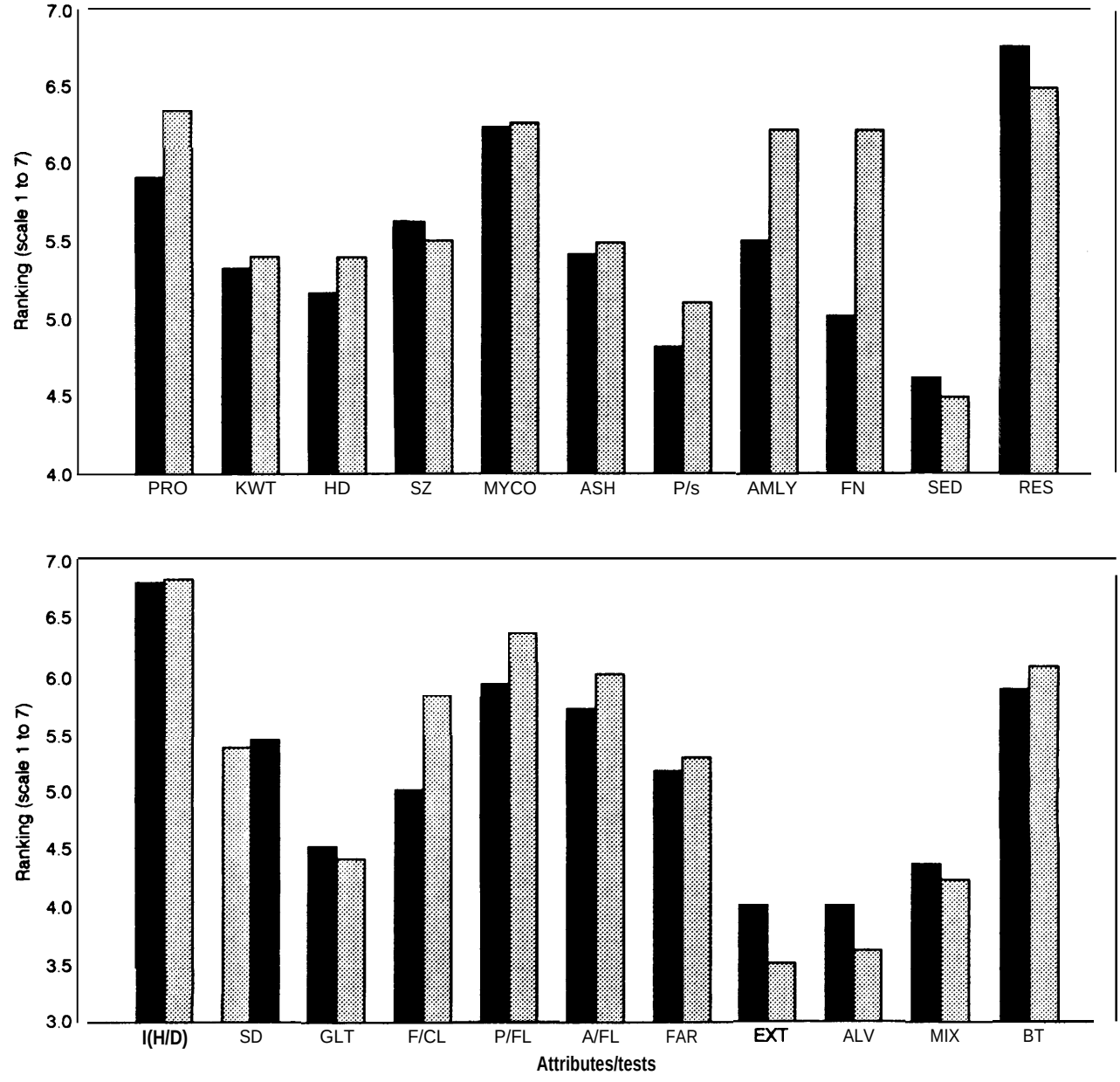
Three main industries account for the majority of corn usage and each one has different requirements. The following is a brief discussion of the important attributes for each industry.

Corn Dry Milling

Several factors affect dry milling performance, yields, and the quality of products derived from dry milling. These factors include:

- corn hardness;
- drying temperature;
- stress cracks;
- broken corn and foreign material;
- kernel size and shape; and
- wholesomeness or freedom from molds, aflatoxin, insects, rodent excreta, toxic substances, odors, and so on.

Figure 4-9. --Importance of Wheat Attributes and/or Tests - Domestic Millers

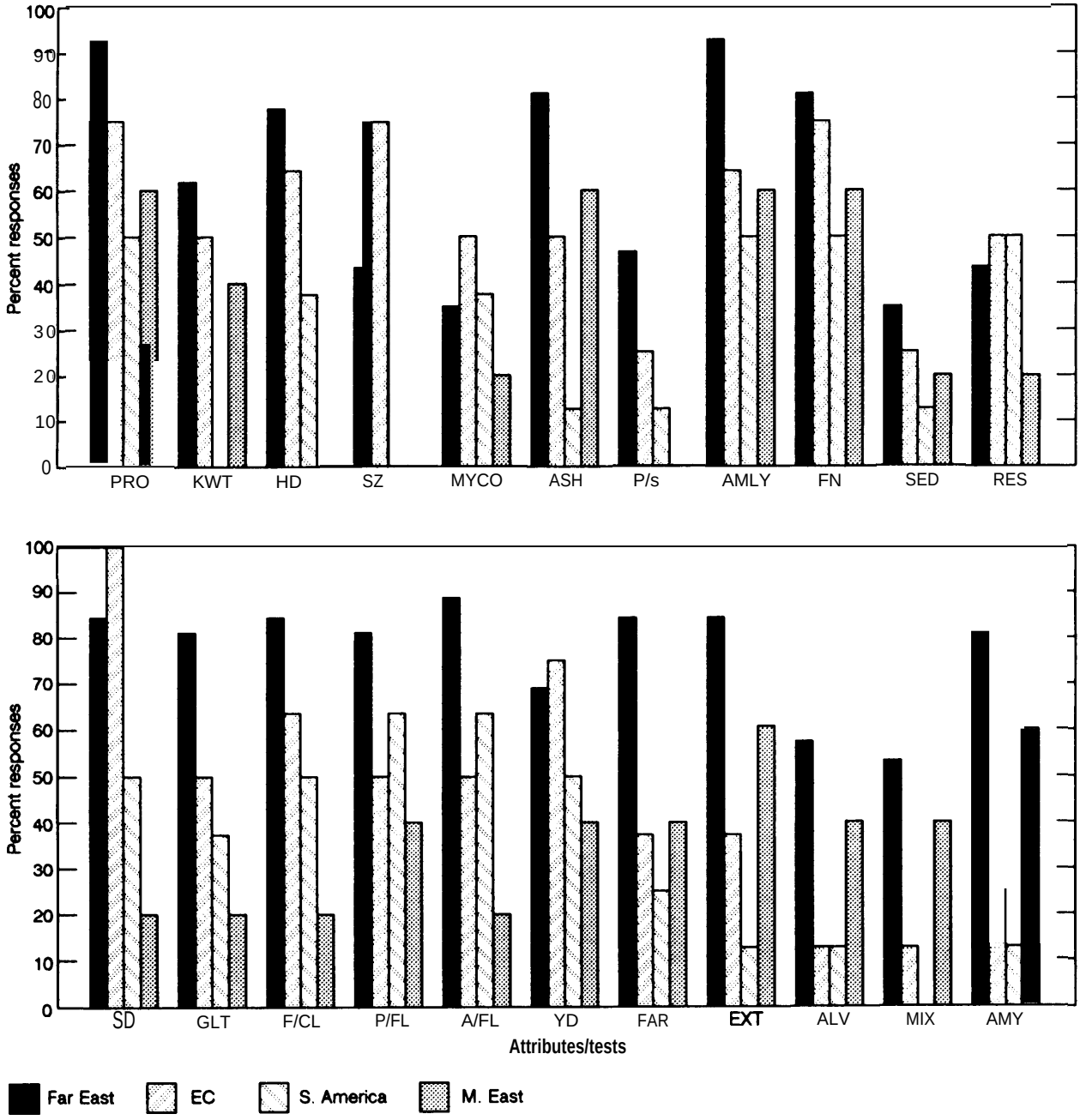


ABBREVIATIONS:

PRO	= Protein	P/S	= Particle size	SD	= Starch damage	EXT	= Extensograph
KWT	= 1,000 kernel weight	AMLY	= Alpha amylase	GLT	= Wet/dry gluten	ALV	= Alveograph
HD	= Hardness	FN	= Falling number	F/CL	= Flour color	MIX	= Mixograph
SZ	= Kernel size	SED	= Sedimentation	P/FL	= Flour protein	BT	= Baking test
MYCO	= Mycotoxins	RES	= Pesticide residue	A/FL	= Flour ash		
ASH	= Wheat ash	I(H/D)	= Insects (hidden/dead)	FAR	= Farinograph		

SOURCE: Office of Technology Assessment, 1989

Figure 4-10.—Importance of Wheat Attributes and/or Tests — Overseas Millers

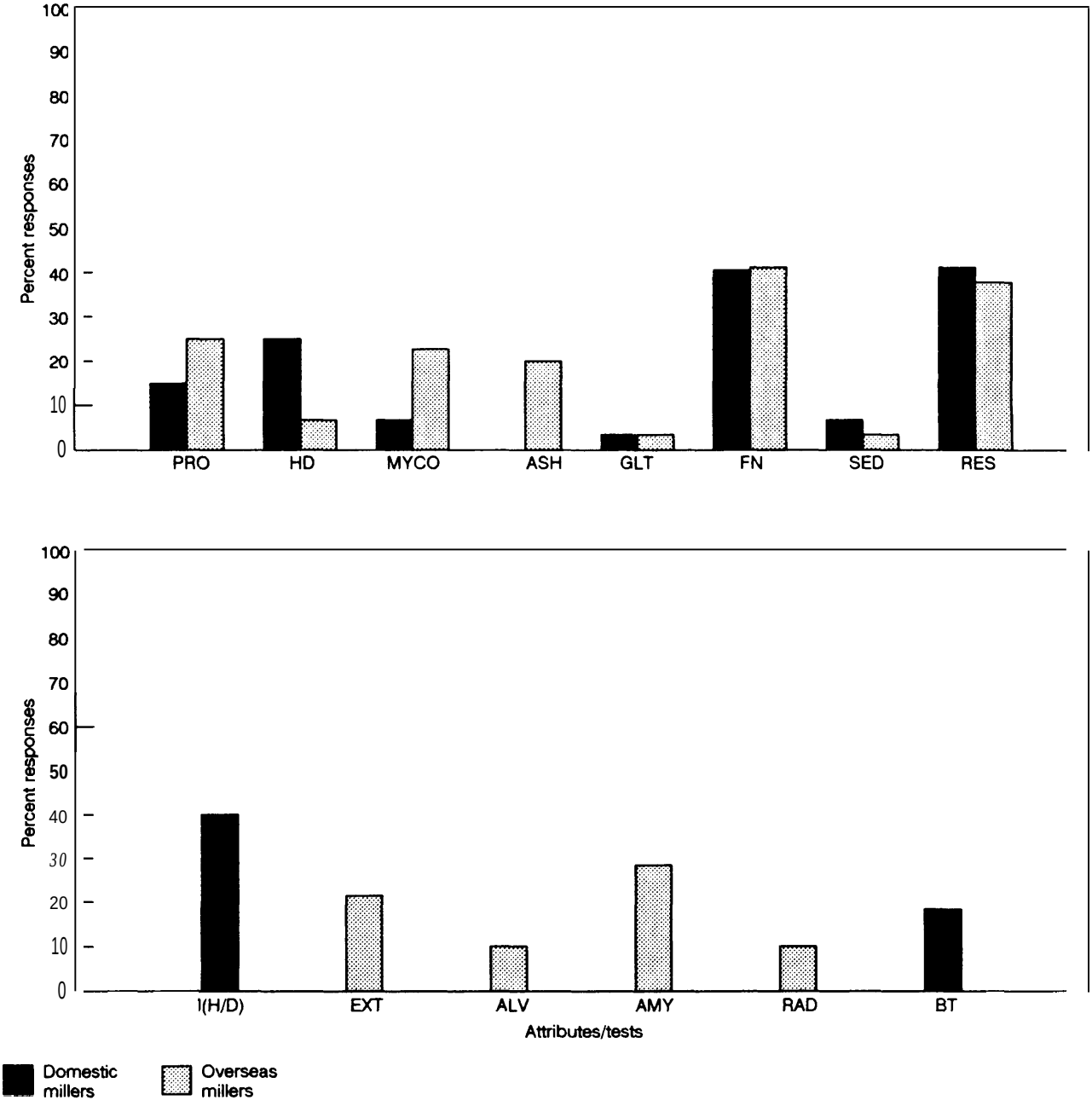


ABBREVIATIONS:

PRO = Protein
KWT = 1,000 kernel weight
HD = **Hardness**
SZ = Kernel size
MYCO = Mycotoxins
ASH = Wheat ash
P/S = Particle size
AMLY = Alpha amylase
FN = Falling number
SED = Sedimentation
RES = Pesticide residue
SD = Starch damage
GLT = Wet/dry gluten
F/CL = Flour color
P/FL = Flour protein
A/FL = Flour ash
YD = Flour yield
FAR = Farinograph
EXT = Extensograph
ALV = Alveograph
MIX = Mixograph
AMY = Amylograph

SOURCE: Office of Technology Assessment, 1989

Figure 4-11.–Additional Tests for Inclusion in Wheat Standards"



ABBREVIATIONS:

PRO = Protein	FN = Falling number	ALV = Alveograph
HD = Hardness	SED = Sedimentation	AMY = Amylograph
MYCO = Mycotoxins	RES = Pesticide residue	RAD = Radiation
ASH = Wheat ash	I(H/D) = Insects (hidden/death)	BT = Baking test
GLT = Wet/dry gluten	EXT = Extensograph	

[a]Percentages are based on number of responses that indicated additional tests are needed

SOURCE: Office of Technology Assessment, 1989

Corn hardness can be defined as the quantity of vitreous or horny endosperm contained in a corn kernel relative to the amount of floury endosperm. Corn hardness is almost entirely a result of corn genotype, but to a limited extent nitrogen, soil fertility, and drought can cause hardness to increase. Dry millers need a hard corn in order to produce high yields of large flaking grits and have even developed approved lists of corn hybrids.

Excessive drying temperatures can lead to corn kernel stress cracking, which has deleterious effects on dry milling yields. The stress crack formation in the horny endosperm is caused by rapidly drying kernels with heated air. Stress-cracked corn not only causes increased breakage during handling, but also reduces flaking grit yields since stress-cracked flakes produce smaller grits when undergoing cooking and pressing through flaking rolls.

Broken corn and foreign material is detrimental to dry milling and no attempt is made to use this material in the milling process. It is removed prior to milling and diverted to hominy feed. Broken kernels affect the tempering process because they absorb moisture faster than whole kernels. Kernel size, shape, and color also affects the dry milling process. Round kernels are more difficult to degerm than flat kernels, and the same is true of small kernels compared with large ones. Color is important to producing corn chips because the alkali cooking process modifies the color. In some cases white and yellow kernels are blended to produce the desired color (5).

Corn Wet Milling

Since the wet milling process involves steeping with elevated temperatures and sulfur dioxide, fungi and other micro-organisms are destroyed (4). Many of the other wholesomeness factors such as insects, mycotoxins, and other debris are not found in the food product after processing but can be found in the feed byproducts if they are present in the corn being processed.

High levels of broken corn and foreign material, breakage susceptibility, and damaged kernels are not desired by the wet milling industry. Broken corn must be removed prior to processing because it affects steeping. High levels of mold-damaged kernels affects germ recovery and crude oil quality. Drying temperature, as discussed in the dry milling section, causes stress cracking and increases breakage susceptibility, which affects starch recovery.

Feed Manufacturing

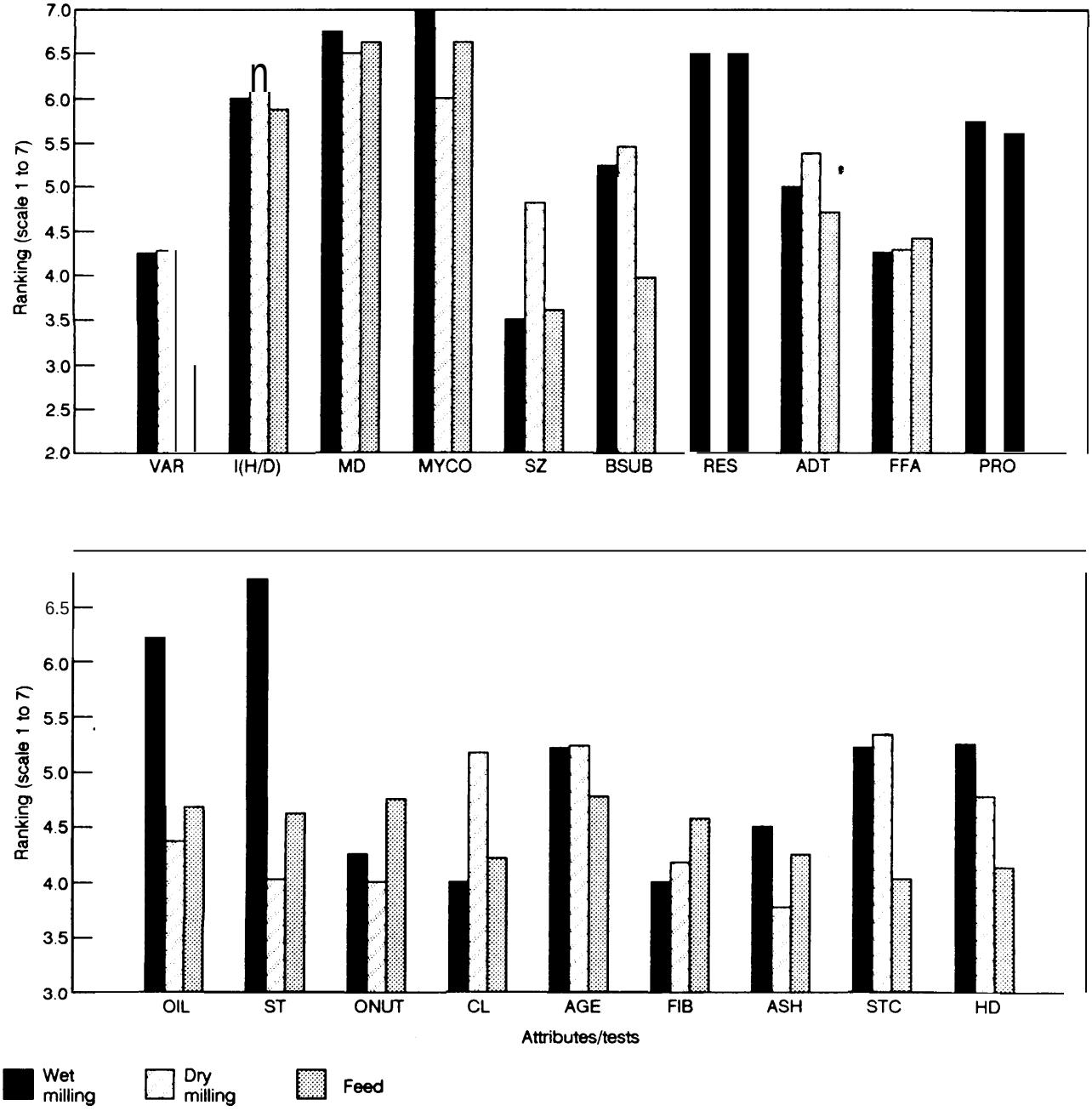
All feed grains are highly palatable to livestock. Corn has the lowest protein content of all feed grains. However, the protein in all feed grains has a relatively low biological value for monogastric animals due to a deficiency of one or more essential amino acids. When formulating diets for poultry and swine, therefore, supplemental protein that adds sufficient amino acids to balance this deficiency must be added. Also, feed grains are extremely low in calcium content and in phosphorus, and deficient in several essential vitamins (6). Therefore, these deficiencies must also be overcome with supplements in various degrees, depending on the type of animal to be fed (3).

Properly balanced diets containing wholesome ingredients are necessary for efficient livestock production. In addition, variations in important intrinsic properties (protein, crude fiber, total digestible nutrients) from published values are detrimental to efficient feed production.

Survey Results

The OTA questionnaire sent to dry millers, wet millers, and the feed manufacturers listed 19 attributes and/or tests not currently found in the corn standard (figure 4-12). With the exception of starch and oil content in the wet millers' rankings, all three industries ranked hidden/dead insects, mold, mycotoxins, and pesticide residue as the most important items. Breakage susceptibility, stress cracks, and hardness, as expected, were ranked higher by wet and dry millers than by feed manufacturers. Protein is considered more important by wet millers and feed manufacturers. Oil and starch content were considered very important by wet

Figure 4-12. – Importance of Corn Attributes and/or Tests



ABBREVIATIONS:

VAR = Variety	**BSUB =** Breakage susceptibility	OIL = Oil
I(H/D) = Insects (hidden/dead)	RES = Pesticide residue	ST = Starch
MD = Mold	ADT = Artificial drying temperature	ONUT = Other nutrients
MYCO = Mycotoxins	FFA = Free fatty acid	CL = Color
SZ = Kernel size	PRO = Protein	AGE = Age

FIB = Fiber
ASH = Ash
STC = Stress cracks
HD = Hardness

SOURCE: Office of Technology Assessment, 1989

millers, but only marginally important by dry millers and feed manufacturers.

Seventy-one percent of the wet and dry millers and 36 percent of feed manufacturers indicated that limits for one or more of the 19 items were being included in contracts. Five items (hidden/dead insects, mold, mycotoxins, pesticide residue, and stress cracks) were found most often in contracts by all industries.

Data from the survey of importers only involved the attributes and/or tests that are included in contracts. Stress cracking was the only one identified by dry millers as having limits included in contracts, whereas five items (protein, fiber, starch, oil, and mycotoxins) were marked by wet millers being included. Overseas feed manufacturers specify limits on four items (protein, fiber, energy, and carbohydrates) in contracts.

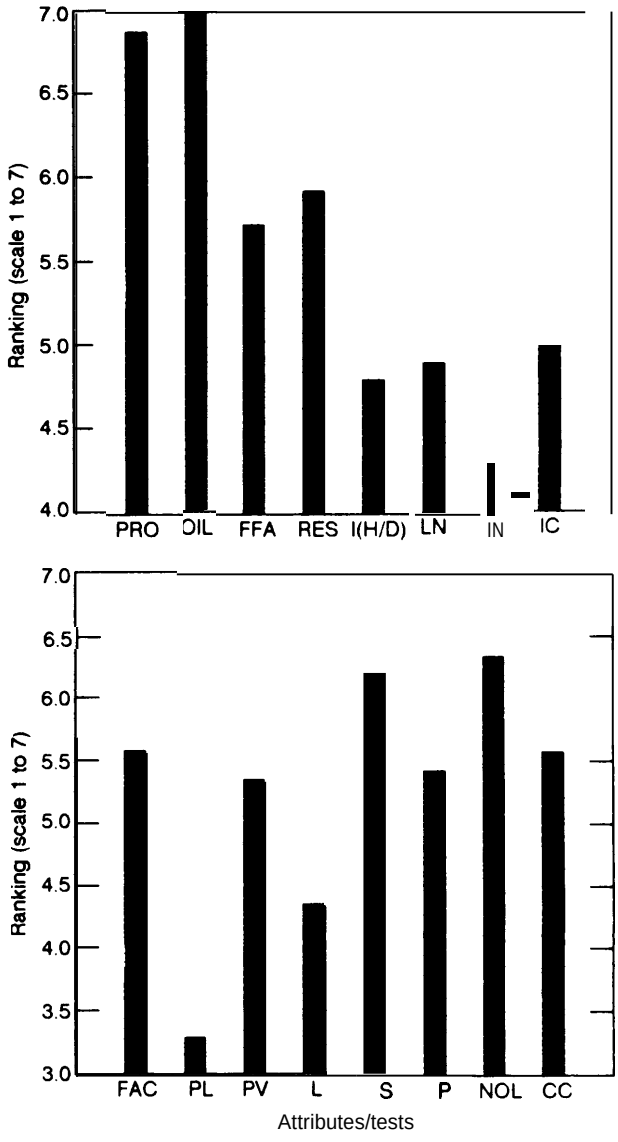
Soybean Processing

The quantity and quality of soybean protein and oil are important attributes to processors since the main products are high-protein meals and oil. Crude soybean oil contains oil-insoluble and oil-soluble impurities that must be removed (1). Oil-insoluble impurities include seed fragments, excess moisture, and waxy fractions that make oil cloudy. Oil-soluble impurities such as free fatty acid, phosphatides, and protein fractions are detrimental to the oil's flavor, odor, color, and stability.

Of 16 attributes and/or tests not currently contained in the soybean standard, soybean processors ranked protein, oil, oil stability, and neutral oil loss as most important (figure 4-13). No limits for any of the 16 items listed, however, are included in contracts.

For overseas soybean processors the importance of items and which items have limits included in contracts were evaluated. Protein, oil and free fatty acid were considered the most important and the only items for which limits are included in contracts.

Figure 4-13. - Importance of Soybean Attributes 'and/or Tests



ABBREVIATIONS:

PRO = Protein	FAC = Fatty acid content
OIL = Oil	PL = Phosphorous level
FFA = Free fatty acid	PV = Peroxide value
RES = Pesticide residue	L = Lipoxygenase
I(H/D) = Insects (hidden/dead)	OS = Oil stability
LN = Lovibond number	HP = Hydratable phosphatides
IN = Iodine number	NOL = Neutral oil loss
IC = Iron content	CC = Chlorophyll content

SOURCE. Office of Technology Assessment, 1989

UNIFORMITY BETWEEN SHIPMENTS

Delivering uniform, consistent quality between shipments has been identified by overseas and domestic industries as important. U.S. industries have more flexibility in handling a shipment that is not up to specification, since the grain can be resold or blended. Many overseas industries cannot do this since they have little or no inventory and each time a shipment arrives they must deal with the quality received.

The need for uniform or consistent quality was documented at the International U.S. Wheat End Use Quality Conference in June 1986 by Dr. Seiichi Nagao from the Nisshin Flour Milling Co., Ltd., Japan, and by Emma B. Laguio, United Flour Mill Co., Ltd., Bangkok, Thailand. Dr. Nagao stated:

> The low reliability of U.S. Hard Red Spring wheat is caused by wide fluctuation both in milling and in baking performance, and it seems to me that the quality fluctuation among cargoes is getting larger and more serious, . . . Besides ash content, almost all quality items including test weight, moisture, protein, flour, yield, the analytical data of flour and baking performance vary very widely. As we are afraid of giving our large customers trouble in their automated baking process by blending a large amount of U.S. Hard Red Spring wheat that varies widely in its baking absorption and dough handling property, it is thought to be a supplementary material usable only with No. 1 Canada Western Red Spring wheat which is more stable in quality (8).

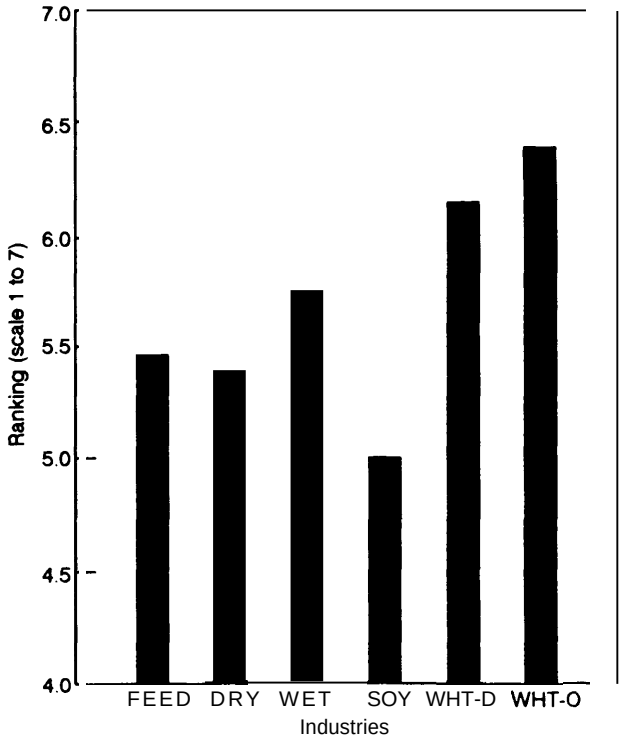
Emma Laguio echoed Dr. Nagao but added that consistency in quality is foremost in the Asian miller's mind.

> Bakers in our region require consistency of quality in flours they use. Flour millers also require consistency of quality in the wheat they will mill. I realize that the attainment of consistent or even near-consistent wheat quality at any given time calls for more than just the acts of mortals. However, there are factors within the producer's control which can and do contribute to quality consistency in wheat. This, I believe is particularly important to Asian millers who are a captive market, so to speak, in the sense that we are obligated to mill whatever wheat we receive (8).

When identifying important grain quality attributes, the system's ability to consistently deliver these attributes can be as big a factor as the attribute itself, as evidenced by these importers' statements. The qualities desired are generally available, given the information collected from the OTA survey. But quality fluctuations between shipments can affect purchasing decisions and the ultimate use of a particular grain.

As part of the OTA survey, each industry was asked to rank the importance of uniformity between shipments (figure 4-14). Domestic and overseas wheat millers ranked the importance of uniformity between shipments as 6 (moderately important) or higher. The wet millers con-

Figure 4-14. - Importance of Uniformity Between Shipments



ABBREVIATIONS:
FEED = Feed manufacturers
DRY = Dry millers
WET = Wet millers
SOY = Soybean processors
WHT-D = Wheat millers (domestic)
WHT-O = Wheat millers (overseas)

SOURCE: Office of Technology Assessment, 1989

sidered uniformity more important than the other corn industries did, while the soybean processors ranked it as 5 (slightly important).

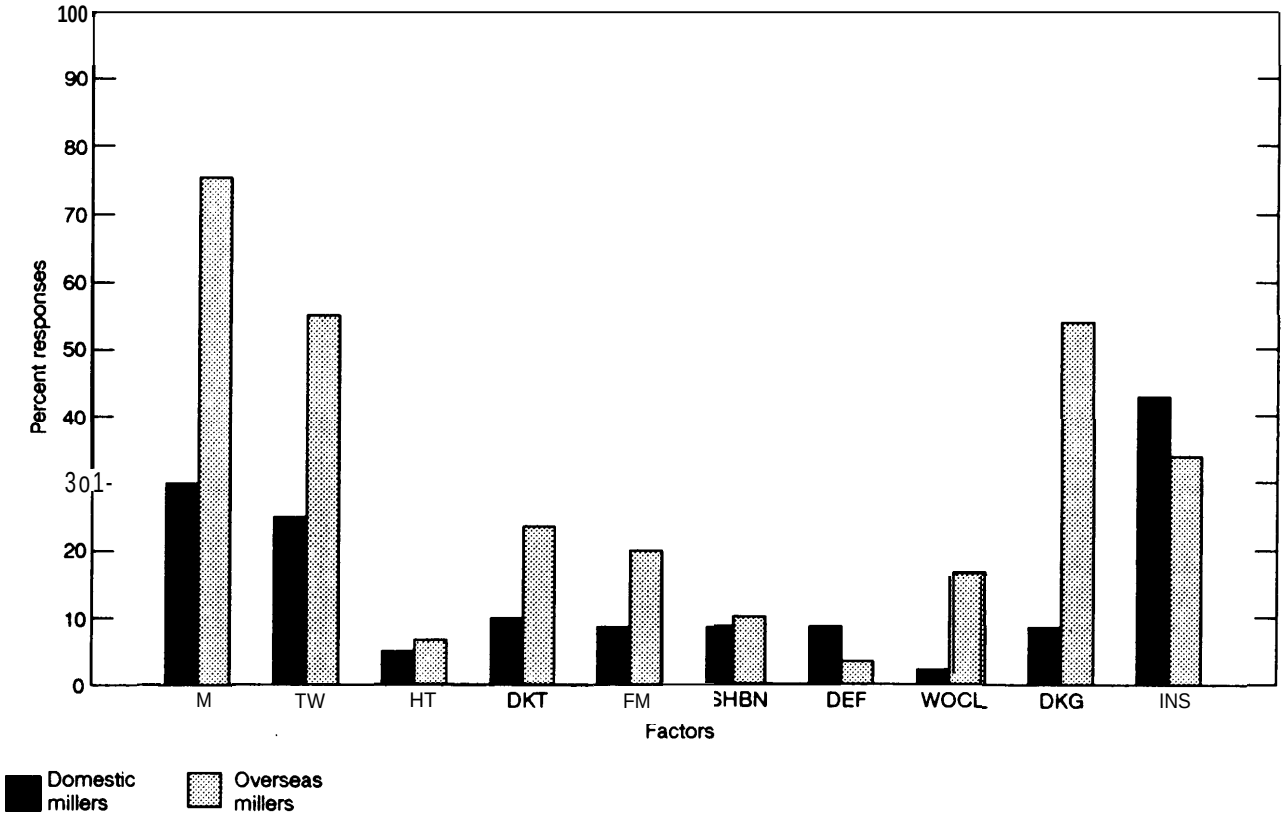
When evaluating future attributes/and or tests for grain, the ability to deliver uniform, consistent quality must be addressed, The importance of delivering consistent quality is evident when examining the factors currently contained in each standard. Significant concern exists for these factors regarding uniformity (figures 4-15, 4-16, and 4-17).

For wheat, moisture, test weight, dockage, and live insects stand out as being critical factors regarding uniformity between shipments to overseas buyers. With the exception of dockage, these factors are also considered the most important in terms of uniform it y between shipments to domestic millers.

Except for moisture, the importance of each factor varies by individual corn industry, Moisture was considered the most important factor overall in terms of uniformity, followed by damaged kernels total.

The importance of uniformity between shipments for attributes and/or tests not currently found in the grain standards again reflects the industries' concerns, Protein content, in the case of wheat, was considered the most important by domestic and overseas millers. Overseas millers showed more concern for dough

Figure 4-15.-Importance of Uniformity on Wheat Standard Factors

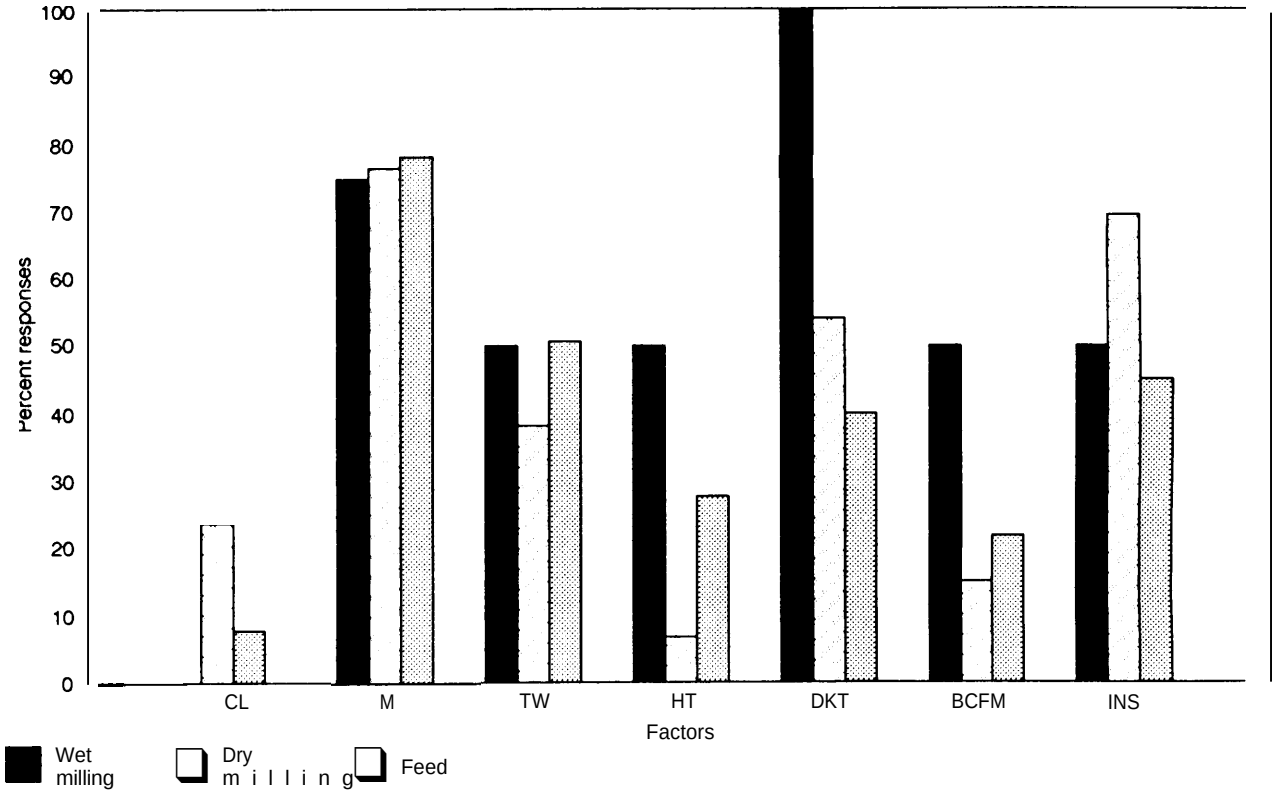


ABBREVIATIONS:

M = Moisture
TW = Test weight
HT = Heat damage
DKT = Damaged kernels (total)
FM = Foreign material
SHBN = Shrunken and broken kernels
DEF = Total defects
WOCL = Wheat of other classes
DKG = Dockage
INS = Live insects

SOURCE: Office of Technology Assessment, 1989

Figure 4-16.-Importance of Uniformity on Corn Standard Factors



ABBREVIATIONS:

CL = Class
M = Moisture
TW = Test weight
HT = Heat damage
DKT = Damaged kernels (total)
BCFM = Broken corn and foreign material
INS = Live **insects**

SOURCE: Office of Technology Assessment, 1989

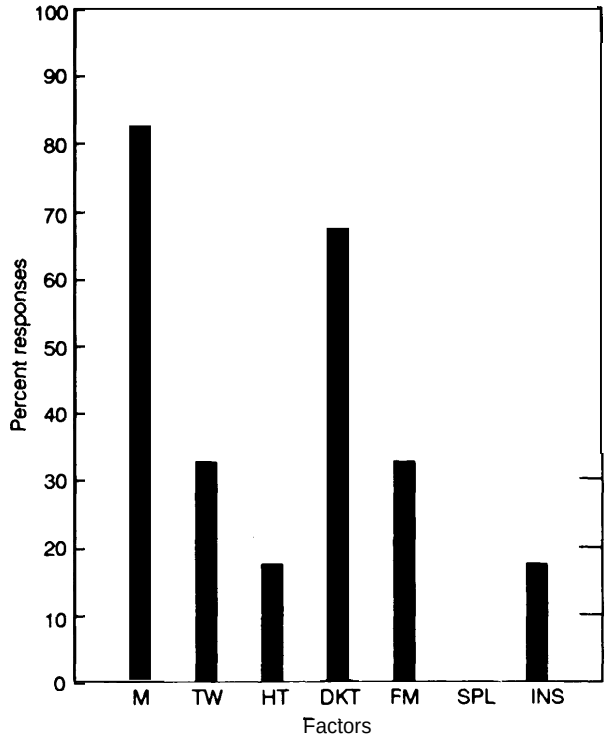
handling tests than did domestic millers, but domestic millers ranked the bake test second in importance. Except for mycotoxins, the three corn industries ranked the items differently, with concerns being evident for the items of particular interest to each. Soybean processors, on the other hand, did not identify any item as being overly important.

DECREASE **IN QUALITY**

Each industry was asked in the OTA survey if quality has decreased as evidenced by any of the factors contained in the grain standards or for the attributes and/or tests listed. The domestic and overseas wheat millers indicated that they have perceived a decline in quality.

Sixty-six percent of the overseas respondents indicated that they have experienced a decrease in wheat quality. Five factors (moisture, heat damage, foreign material, wheat of other classes, and dockage) were identified as having gotten worse. Domestic millers also identified these factors, but ranked four others (test weight, damaged kernels total, shrunken and broken kernels, and live insects) as the areas showing declines. Both groups indicated that quality has decreased in terms of protein and

Figure 4-17. - Importance of Uniformity on Soybean 'Standard Factors



ABBREVIATIONS:
M = Moisture
TW = Total weight
HT = Heat damage
DKT = Damaged kernels (total)
FM = Foreign material
SPL = Splits
INS = Live insects

SOURCE: Office of Technology Assessment, 1989

the falling number test. Overseas millers also identified wet/dry gluten and the farinograph test, whereas domestic millers expressed concerns for the presence of hidden/dead insects.

The results from the survey regarding decreases in wheat quality were also reported by Emma Laguio (tables 4-4 and 4-5), who pointed out at the International End Use Quality Conference that test weight, kernel size, and kernel hardness have been decreasing over time. Lower water absorption and shorter mixing times of spring wheat, as demonstrated by the farinograph test, have been evident since 1983. Further, it was reported that 1985 and 1986 arrivals show significantly lower water absorption and mixing time as compared with the shipments of the 1970s, and that flour doughs are softer and slightly more extensible. These conditions, in his opinion, indicate lower gluten strength.

FINDINGS AND CONCLUSIONS

All processors desire grain that is free from pesticide residues, molds, mycotoxins, toxic weed seeds, and insects and insect fragments, and that otherwise is in a sanitary condition, The importance, however, of physical and intrinsic quality characteristics can vary by grain and by processor and are influenced by the grain's ultimate use. Each industry, domestic and overseas, defines quality in terms of the areas important to its market, as the OTA survey of buyers confirmed.

Standards

Domestic and overseas wheat millers consider the factors contained in the wheat standard important, but indicated a need for additional tests. However, overseas millers generally consider the factors contained in the standard as slightly more important. Live insects were considered the most important factor by both. Domestic millers include in their contracts limits for the factors contained in the standard more often than overseas millers, who purchase on grade only with limits.

Overall each corn industry considers the factors contained in the standard as important. Differences exist between industries regarding the importance of each factor, but wet millers consistently ranked the factors higher than dry millers and feed manufacturers did, Differences

Table 4-4.—Quality Characteristics of U.S. No. 2 or Better DNS, 15 Percent Protein, 1975-86 Shipments to Thailand

	1975	1978	1981	1983	1984	1985	1986
Wheat characteristics:							
1,000 kernel weight (g)	29.2	31.4	32.4	32,1	31.9	**28.3**	27.4
Grain hardness (o/o)	—	13.2	12.4	11.5	12.3	**15.2**	15.2
Moisture (o/o)	12.1	12.5	13.0	11.8	11.2	**11.6**	12.3
Ash (%)	1.50	1.52	1.53	1.64	1.63	**1.59**	1.60
Protein (o/o, as is M. B.)	15.2	15.1	14.7	15.0	15.0	**15.0**	15.2
Protein (o/o, 12.0°/0 M. B.)	15.2	15.2	14.9	15.0	14.9	**14.9**	15.2
***Flour characteristics (milled* in Buhler** Mill MLU-2020):							
Flour extraction (o/o)	—	73.0	***73,5***	73.4	74.1	72.6	70.6
Ash (%)	***0.53***	**0.41**	***0.42***	0.51	0.48	0.46	0.46
Protein (o/o, 13.0°/0 M. B.)	14.5	14.5	***13.8***	14.2	14.0	14.2	14.2
Wet gluten (%)	40.2	38.5	***37.5***	38.2	38.0	38.0	39.5
Amylogram peak viscosity (BU)	–	620	***545***	728	869	805	500
Farinogram:							
Absorption (o/o)	69.3	68.8	67.5	66.0	65.4	64.3	64.9
Peak time (min.)	14.5	11.5	11.5	8.0	9.5	9.5	8.5
Mixing tolerance index (BE)	25	15	15	20	20	25	25
Stability (min.)	20	26	26	16	20	25	20
Calorimeter (BU)	87	90	92	77	85	89	89
Extensogram:							
45 minutes							
Extensibility (mm.)	232	240	**244**	262	242	235	236
Resistance	240	265	**275**	256	324	299	320
Area (sw. cm.)	127	150	**161**	174	188	186	192
135 minutes							
Extensibility (mm.)	181	214	218	246	255	235	240
Resistance	480	345	320	283	382	386	400
Area (sq. cm.)	176	171	209	218	222	230	217

SOURCE U S Wheat Associates, "U S Wheat End Use Quality Conference," published proceedings, Washington, DC, June 1986

Table 4-5.—Quality Characteristics of U.S. No. 2 or Better HRW, 11 Percent Protein, 1981-86 Shipments to Thailand

	1981	1982	1983	1984	1985	1986
Wheat characteristics:						
1,000 Kernel weight (g)	30.5	31.7	31.6	31.7	31.2	28.9
Grain hardness (o/o)	11.4	11.8	12.5	14.2	16.1	16.5
Moisture (o/o)	10.0	10.6	11.2	11.1	11.4	10.9
Ash (%) 1.50	1.53	1.47	1.51	1.55	1.44	1.55
Protein (o/o, as is M. B.)	11.9	12.0	11.8	12.2	12.0	11.8
Protein (o/o, 12,0°/0 M. B.)	11.6	11.8	11.7	12.1	11.9	11.6
Flour characteristics (milled in Buhler Mill MLU-202):						
Flour extraction (o/o)	72.0	71.0	72.3	75.6	71.9	***73.4***
Ash (o/o) 0.53	0.40	0.41	0.46	0.46	0.43	***0.44***
Protein (o/o, 13.0°/0 M. B.)	10.8	10.7	10.8	11.1	10.9	***10.5***
Wet gluten (o/o)	28.6	29.6	29.8	31.2	30.0	***20.4***
Amylogram peak viscosity (BU)	655	790	760	800	600	***700***
Farinogram:						
Absorption (o/o)	63.3	63.2	62.0	63.5	62.1	***60.1***
Peak time (min.)	4.0	6.5	5.25	6.0	6.5	1.75
Mixing tolerance index (BU)	20	30	30	25	25	10
Stability (min.)	15	13	12	16	15	17
Calorimeter (BU)	71	68	66	74	69	51
Extensogram:						
45 minutes						
Extensibility (mm.)	200	207	200	215	219	185
Resistance	265	350	290	320	310	330
Area (sw. cm.)	116	156	146	142	144	122
135 minutes						
Extensibility (mm.)	189	203	207	204	192	179
Resistance	318	390	331	382	390	440
Area (sq. cm.)	130	178	158	175	168	160

SOURCE U S Wheat Associates, "U S Wheat End Use Quality Con ference," published proceedings, Washington, DC June 1986

also exist between industries concerning which factors are included in contracts. The factors having limits included in contracts by domestic processors are similar to those of their overseas counterparts, however.

A number of factors currently in the soybean standards are not considered important by processors. These include class, test weight, and splits. Moisture and heat damage are considered the most important factors by domestic processors, while overseas processors consider moisture and foreign material as important.

Important Attributes Not in Standards

No one set of quality attributes—e.g. high v. low protein or strong v. weak flour-meets the demands for all wheat products. Domestic millers do agree, however, that at least eight factors are important no matter what the end-product may be: protein, mycotoxins, alpha amylase, falling number, pesticide residue, hidden/dead insects, flour protein, and bake test. Overseas millers differed by region of the world in their response to which attributes are important. Nevertheless, four factors were common across all regions: protein, pesticide residue, falling number, and dough handling tests. The Far Eastern countries considered these factors to be of greater importance than other regions of the world.

Domestic and overseas wheat millers indicate that additional tests are needed. Falling number and pesticide residue were the items most often identified by both groups. Overseas millers also specified dough handling tests such as farinograph and alveograph as important additional tests, while domestic millers indicate a strong preference for a test for hidden/dead insects.

Determining which attributes are important for corn is industry-dependent except in areas regarding wholesomeness, health, and safety concerns. Quality attributes vary by requirements of each corn industry, Items such as stress cracking, breakage susceptibility, and hardness are more important to wet and dry millers than to feed manufacturers. Attributes such as pesticide residue, mold, mycotoxin, and hidden/dead insects are important to all industries.

Commonality of important quality attributes is more evident in soybeans than in wheat or corn between domestic and overseas processors. The most important attributes are protein, oil, and free fatty acid content.

Uniformity Between Shipments

The grain system's ability to deliver the important quality attributes consistently is as important as the attributes themselves. Quality fluctuations between shipments significantly influence purchasing decisions. Problems with uniformity are especially acute in wheat and corn. Uniformity between shipments will become more important as processing technologies become more sophisticated and more end-uses are found for each grain.

In wheat, overseas millers indicate that the factors contained in the wheat standard that are most affected by lack of uniformity are moisture, test weight, dockage, and live insects. With the exception of dockage, uniformity in these factors was also considered the most important by domestic millers. Protein, dough handling tests, and the bake test were also identified as items of concern.

In corn, moisture was the most important uniformity concern, followed by damaged kernels, Mycotoxin was considered important by all three corn industries, with other concerns being expressed for items of particular interest to each industry.

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