Chapter 14

Food Quality: The Relevance of Food Grades

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INTRODUCTION

Many consumers are expressing concerns over the safety and the quality of food, and these concerns extend to the use of new agricultural technology in food production. Information about food quality can be provided through labeling, brand names, price, and grades. Food grades, for example, are used to classify products according to certain quality characteristics.

The objective of a grading system is to sort a population with heterogeneous characteristics (i. e., a group of foods) into lots of more uniform or homogeneous characteristics. An effective grading system uses personal observation and testing to provide information that reduces user-perceived risks associated with product quality. Grading also aims to improve product uniformity within a particular grade and serves as the basis for price. Grading facilitates an equitable incentive system stimulating farmers to produce commodities in response to consumer preferences. As a consequence, grading transaction costs are lowered and overall marketing efficiency is enhanced. Sorting via grades also facilitates trade because many consumers are likely to lack the expertise or time to identify meaningful qualit y characteristics from heterogeneous lots of any particular commodity.

Grades for beef, fruits, and vegetables are used throughout the marketing system, i.e., by farmers, processors, wholesalers, retailers, and consumers. However, grades for some commodities (i.e,, pork) are used almost entirely at the producer-processor level. At least 70 percent of pork is cured, smoked, or further processed before it reaches the consumer, whereas most beef reaches the consumer in the fresh form; this can explain the greater need for beef quality grades at the consumer level. Pork is also more uniform from a quality point of view than beef. Most hogs are marketed at about the same age after being fed a high-concentrate diet. Beef cattle, on the other hand, may be marketed as ‘‘grass fat” or after being fed high-concentrate rations for varying lengths of time, and are slaughtered at a wide range of ages. Both factors influence tenderness and appearance of fresh beef.

The use of grades as a proxy for quality is criticized heavily for at least two reasons. First is the concern about the usefulness of current grading systems, especially for the livestock industries. The criticism focuses on the relevance of the criteria used and on the accuracy of measurement, and the value differentiation for users.

Second is the concern about the attributes on which grading is based and resulting economic incentives. For example, fruit and vegetable grades are based on characteristics that affect consumers’ senses, such as touch, sight, and taste, and on shelf-life considerations or some combination of these factors. These current sensory-based grade attributes, critics argue, indirectly may encourage the use of chemicals during the production process. For example, when the top grade of a fruit or vegetable is based on sensory characteristics, it provides economic incentive to apply chemicals so as to ensure minimal blemishes and vibrant skin color. If the standards were shifted away from sensory characteristics, fewer chemicals probably would be used because less economic incentive would exist to use chemicals.

Consumers are increasingly aware of and dubious about the use of chemicals, or chemically based ingredients, in the production and preservation of the food supply. In addition to concern that chemicals used in the production process may be deleterious to the environment, concern exists that chemical ingredients in or on food maybe injurious to human health, perhaps in ways yet unknown to the scientific community.

However, grading standards and the process of grading should not be confused with food safety. Food safety is a question of determining whether or not the ingestion of a particular food or food ingredient may be injurious to human health. Only food items already determined to be safe are graded.

This chapter focuses on two concerns 1) the usefulness of current grades and 2) the potential for alternative grade attributes. An exhaustive analysis of all grading systems is beyond the scope of this report. Instead, a case approach is used to focus on these issues. The first case study focuses on the livestock industry —specifically pork. The second focuses on the fruit and vegetable industry.

THE PORK GRADING SYSTEM[1]

USDA Grade Standards

Background

Grade standards for pork were established by the U.S. Department of Agriculture (USDA) in the early 1930s. Barrows and gilts are the primary market animals. Grades for barrow and gilt carcasses, i.e., U.S. No. 1, No. 2, No. 3, and No. 4 are based on two general considerations: 1) quality—which includes characteristics of lean and fat, and 2) expected yield (i.e., in proportion to total weight) of the four lean cuts (ham, loin, picnic shoulder, and Boston butt).

Two general levels of quality are recognized: 1) acceptable and 2) unacceptable. Presently, the quality of lean cuts is best evaluated by a direct observation of its characteristics on a cut surface. Standards indicate that when a cut surface of a major muscle is available, quality determination shall be based on the characteristics of the loin eye muscle at the 10th rib. When this surface is not available, other exposed major muscle surfaces can be used for comparable quality determinations. Generally, packers do not elect to reduce the value of a loin by cutting the loin at the 10th rib or to expose any of the major muscle surfaces. When a major muscle cut surface is not available, the quality of the lean is to be evaluated indirectly based on quality-indicating characteristics of the carcass. These include firmness of the fat and lean, amount of feathering (fat streaking in tissue) between the ribs, and color of the lean. While current standards employ feathering as a quality indicator, there is no scientific evidence that feathering is related to quality.

A barrow or gilt carcass with acceptable lean quality and belly thickness is placed in one of four grades, depending on the backfat thickness over the last rib, and the degree of muscling (thickness of muscling in relation to skeletal size). These two factors together indicate the expected carcass yields of the four lean cuts. These yields are based on cutting and trimming methods used by the U.S. Department of Agriculture in developing the standards (table 14-1). Other cutting and trimming methods may result in different yields.

Adoption of USDA Grades

Use of USDA grade standards is voluntary. However, if a packing plant decides to use grade standards and designate the U.S. grade on a package label, they must use USDA's grade standards.

A USDA study of 12 packers in 1981 and 1982 found that none of the plants used the USDA grading system (66). This may be attributable in part to the fact that USDA grade standards had not changed since 1968, whereas the characteristics of the market hog population had changed significantly. In 1981–82, 71.7 percent of the market hogs were graded U.S. No. 1, and 24.4 percent were graded U.S. No. 2; these USDA standards were not effectively discriminating among hogs varying significantly in value. Most packers developed their own grading systems in order to differentiate among pork carcasses (one plant had no grading system). Because each packer's grade and evaluation system was individually designed, grade criteria, descriptive terms used for grades, and evaluation methods varied among packers. Among the factors used to determine grading standards were backfat, muscling, percentage of carcass weight consisting of primal cuts, and conformation. Packer employees primarily used visual appraisal for grading. In 1985 the USDA changed the backfat standards for its grades (table 14-1), but a study of market hog characteristics from five plants in the South and Midwest predicted that 98 percent of the pigs would be in the U.S. No. 1 or No. 2 grade (52). Thus, USDA grades still do not adequately differentiate carcass quality. Overall, pork carcass characteristics have improved to where most meet the standards for the top USDA grades.

Packer grading and evaluation systems also have evolved over the past decade and now have little in common with the USDA grading system. A 1990 Iowa State University survey of 12 of the largest pork slaughter firms found that all large packers now are using carcass weights in their evaluation procedure. Four of the largest packers indicated that actual backfat measurements were the primary basis for their internal evaluation system and their carcass merit buying systems (though the grade could be modified by extremes in muscling noted by visual evaluation). Where backfat measurements were employed, the top grades often had much lower backfat thresholds than USDA grades currently do, with one at 0.6 inches of backfat or less, and two at 0.8 in. or 0.75 in. or less. Seven firms reported currently using or switching soon to the use of the Fat-o-Meter, which calculates percent lean in the carcass from the backfat measurement (taken 2½ inches off the midline of the carcass at the 10th rib)

[1] This analysis is based on the OTA commissioned background paper "An Analysis of the Pork Grading System: Needed Adjustments, " by James Kleibenstein, Marvin Hayenga, Lauran Christian, Kenneth Prusa, Robert Rust (all associated with Iowa State University); and John Forrest, AlIan Schinckel and Max Judge with Purdue University (31).

Table 14-1—Expected Yields of the Four Lean Cuts, by Grade, Based on Chilled Carcass Weight[a]

Grade	Yield
U.S. No 1	60.4 percent and over.
U.S. No 2	57.4 to 60.3 percent.
U.S. No 3	54.4 to 57.3 percent.
U.S. No 4	less than 54.4 Percent.

*These yields will be approximately 1 percent lower if based on hot carcass weight.

SOURCE: U.S. Department of Agriculture.

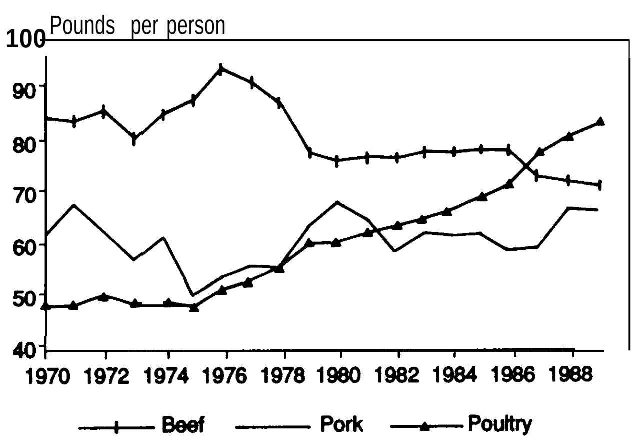
and the loin muscle depth at that location. The percent lean in the carcass then serves as the basis for grading.

In summary, the current USDA pork carcass grading system already is significantly out of step with industry systems: changes in pork carcass composition brought on by new growth promotant technologies may cause further divergence of government and industry grading systems. The USDA pork grades are primarily employed in Federal-State market news and price reporting for live hogs rather than in packing plants. This contrasts with the USDA beef grading system, which is used extensively by beef packing plants for price reporting. In 1989, the American Meat Institute reported that 56 percent of the beef produced was quality-graded, and 65 percent was yield-graded using USDA standards.

Changing Public Concerns and Expectations

Annual per capita consumption of red meat has been declining (figure 14-1) as poultry and fish have been substituted for red meat. The dramatic increase in poultry consumption reflects the aggressive marketing of poultry

Figure 14-1—Per Capita Pork, Beef, and Poultry Consumption, United States, 1970-1989



SOURCE: U.S. Department of Agriculture.

products, their lower relative price, and the response of consumers to fat and cholesterol concerns. Consumption of all meat has trended upward overtime. Total per capita consumption of red meat and poultry reached a record level in 1989 of 220 lbs. per capita, compared with 200 lbs. in 1970 and 170 lbs. in 1960 (figure 14-1). While annual per capita consumption of pork varies cyclically in the United States, there has been little change in pork consumption levels over the long term. Annual per capita consumption of beef, however, has declined dramatically; from 94.2 lb. in 1976 to 71.0 lb. in 1989.

Consumer preferences and attitudes *regarding* meat products have a major influence on meat and meat product demand. Consumer perceptions of product quality and healthfulness, product convenience, cultural or ethnic background, household age composition, lifestyle, and price all impact purchase decisions. Health concerns related to fat and cholesterol levels can affect some consumers' attitudes and preferences regarding pork and beef. These have likely led to changes in demand for meat products. These shifts are difficult to measure accurately, and their impact on purchase patterns are not well documented; it seems likely, however, that health and diet issues will be major factors influencing the future demand for pork and beef. In addition, the need for better nutritional labeling on food products is receiving attention. Healthfulness of food products may be a major driving force in future food policy and consumer purchasing decisions.

A series of Food Marketing Institute (18, 19, 20) consumer surveys document the evolution of factors influencing consumer food purchases. Taste is clearly the leading factor, with 90 percent of consumers surveyed in 1991 considering it very important, and 8 percent somewhat important. Nutrition, product safety, and price ranked high, with 71 to 75 percent of shoppers considering each very important.

At various times nutrition has not been so important to consumers. In 1983, 64 percent of supermarket shoppers were very concerned about nutrition, whereas in 1987, 54 percent indicated this level of concern, and 40 percent were somewhat concerned. In 1991, 75 percent of shoppers surveyed considered nutrition very important, with 22 percent considering it somewhat important in food selection. In food selection decisions, concern about overall nutritional issues is being replaced by concern for specific nutritional components, such as (in order of decreasing importance) fat content, cholesterol level, salt content, calories, vitamin/mineral content, and preservatives (20). Some of those specific concerns were evident in the 1983 survey as well.

Preservatives and chemical additives used in food preparation have emerged as a major consumers concern in recent years. In 1991, 80 percent of shoppers surveyed considered chemical residues in foods a serious hazard (20). The presence of antibiotics and hormones in poultry and livestock feeds was ranked as the second most serious hazard (56 percent). Irradiation was viewed as a serious hazard by 42 percent of the respondents, closely followed by nitrites at 41 percent.

A recent National Research Council report indicates that Americans consume too much fat with consequential nutrition-related health problems (41). A common method to reduce fat in meat products is trimming. Perhaps a more efficient method is the production of leaner animals (41). The pork industry has attempted to reduce the fat content in fresh pork significantly through selective breeding (genetics) and diet and management practices (58). Technological advancements, such as growth promotants and application of genetic engineering, offer the opportunity to markedly improve body composition of pigs before slaughter.

Consumers also are increasingly desirous of product uniformity. While level of desired quality varies among consumers, an individual consumer typically prefers products of uniform quality, as exemplified by the success of many fast-food establishments such as McDonald's, Wendy's, Kentucky Fried Chicken, etc. A visit to the local meat counter, on the other hand, illustrates the lack of uniformity in pork products—present grading systems do not directly reflect product quality.

New *Technologies and Implications for Pork Grading*

A young animal develops lean muscle more rapidly than fat; but as the animal matures, fat accumulates more rapidly than lean. With increasing consumer concerns about fat, it is advantageous for pork producers to shift the growth pattern away from fat accumulation to lean tissue accumulation, particularly during the finishing phases of production. In pork production, recombinant porcine somatotropin (pST) and beta-agonist administration (discussed in ch. 3), shifts the growth response from fat accumulation in pigs to deposition of lean tissue.

Porcine Somatotropin

As discussed earlier, carcass characteristics such as backfat thickness and carcass weight currently determine USDA carcass grade. Thus, changes in the carcass composition that result from use of pST or beta agonists can impact the present grading standards.

Table 14-2—influences of pSt or Ractopamine on Production and Carcass Characteristics of Pigs[a]

	pST[b] (in percent)	Ractopamine[c] (in percent)
Feed efficiency	+21 .1	+ 12.7
Average daily gain	+ 15.2	+ 8.4
Average backfat	– 24.8	– 15.3
Loin eye area	+ 18.5	+ 16.3
Muscle mass	+ 9.9	+ 9.3
Carcass yield[d]	-2.4	+ 1.4

[a]Expressed as an increase or decrease as compared with controls,
[b]Summary of 20 research trials.
[c]Summary of up to 17 research trials.
[d]Hot carcass weight divided by live weight X 100.

SOURCE: D. Zimmerman, "Growth Enhancers," Proceedings on New Swine Growth Enhancers, Iowa State University, 1989.

Zimmerman (70) summarized the available studies that evaluated the impact of pST administration on lean meat production and feed efficiency (table 14-2). The magnitude of response of pST administration varies from study to study and depends on frequency of administration, pST dose level, time of administration, genotype, gender, energy intake, and protein and amino acid intake.

In 20 research trials evaluated by Zimmerman, pST was injected daily at dosages from 15 to 100 ug/kg body weight. Pigs weighed 40 kg or more at the beginning of the treatment period and were fed a diet containing at least 16 percent protein. In many cases diets were supplemented with additional lysine. The average daily gain of pST-treated pigs was 15.2 percent higher than that of controls. Feed efficiency was 21.1 percent higher.

The use of pST has a positive impact on most carcass characteristics. Average backfat thickness decreased by 24.8 percent, loin eye area increased by 18.5 percent, and quantity of muscle mass increased by 9.9 percent with pST administration. In general, the carcass percent lean, which was 52 percent for control pigs, was 64 percent for pST pigs (4); the actual differential depended on the level of pST administered. Studies have shown percent lean increases of 15 to 25 percent. Dressing percentage (carcass yield) decreased by 2.4 percent when pST-treated pigs were compared with controls.

A rapidly accumulating body of data indicates that administration of pST to finishing pigs alters the yield and distribution of wholesale cuts in the carcass. Weight and percentage of lean cuts are significantly increased (ham, 12 percent; loin, 11 percent; Boston butt, 12 per-

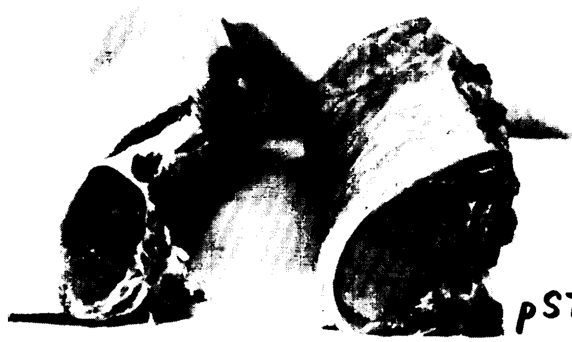


Photo credit: Terry *Etherton, Pennsylvania State University*

Comparison of pork loins that show the effect of pigs treated with porcine somatotropin **(pST).** The **loin-eye area of the loin treated with pST is 8 square inches; the control is 4.5 square inches.**

cent; picnic, 9 percent) whereas weight and percentage of fatty cuts are reduced significantly (belly, 13 percent; jowl, 32 percent) (6, 12).

Proximate composition of the skeletal muscle exhibits a dose-dependent decrease in lipid concentration and a small but significant increase in protein concentration with pST administration (5, 6, 39, 47, 48). Cholesterol concentration of the loin muscle is not altered, and only minor increases in percentage of polyunsaturated fatty acids are observed in the subcutaneous or intramuscular fat of pST-treated pigs (6).

Although data are sparse, little indication exists of any change in mineral concentrations (22) or vitamin content of muscle (46) with administration of pST. Therefore, the most significant effects of pST on nutrient composition of edible tissues is reduction of neutral lipid concentration. Several investigations indicate that cooking loss and sensory characteristics of fresh pork are not adversely affected by pST administration, unless very high doses are administered (5, 6, 15, 22, 47, 64).

In a study that evaluated consumer reaction to pork from pigs treated with pST, nearly 1,200 consumers sampled broiled loin chops from pST-treated and control pigs. Pork from pST-treated pigs was favored by 58.8 percent of the participants for its tenderness, by 60.6 percent for its juiciness, and by 53.7 percent for flavor (49).

In another study, members of 114 Des Moines households (414 people) compared boneless loin roasts from pigs treated with and without pST (17). Overall, no difference was noted in how individuals liked the two roasts. Roasts from pST-produced pigs were judged larger and leaner than control roasts.

pST On-Farm Study

Most studies of pST's effects on pork production and carcass characteristics have been conducted within an experimental and control setting. The expected production responses to pST under normal farm conditions were studied on 15 Iowa pork production operations (50) at Iowa State University. Some pigs were grown to the normal market weight (109 kg) while others were taken to 131 kg before marketing.

The administration of pST had a dramatic positive effect on packer-determined carcass grades (table 14-3). Only 18 percent of control carcasses graded No. 1, whereas 41 percent of the pST (109 kg) group and 69 percent of the pST (131 kg) group graded No. 1. Over 90 percent of the pigs administered pST graded a No. 3 or better, versus only 75 percent of the control hogs. Even though allowances were made for increased backfat with heavier weight pigs a substantial improvement in grade was noted with pST use. However, dressing percentage (hot carcass weight as a percent of live weight) was depressed slightly due to pST administration (table 14-4).

Beta-Agonists

Zimmerman (70) also summarized the large number of research trials that have involved the use of ractopamine in finishing pigs (table 14-1). As with pST, re-

Table 14-3—Effect of Porcine Somatotropin (pST) Administration on Pig Growth Performance

Treatment[a]	Control/ 109 kg (n = 15)	pST/109 kg (n = 12)	ST/131 kg (n = 13)
Start weight (kg)	69.3	69.0	69.3
Final weight (kg)	109.3	111.5	126.3
Gain (kg)	40.0	42.6	57.4
Feed (kg)	144.3	125.6	173.5
Feed/Gain	3.6	3.0	3.0
Average daily feed (kg)	2.7	2.4	2.4
Average daily gain (kg)	0.76	0.81	0.79

[a]control/109 kg targeted for slaughter at 109 kg, a summary of 15 farms averaged over 533 pigs; pST/109 kg targeted for slaughter at 109 kg, a summary of 12 farms averaged over 373 pigs; pST/131 kg, targeted for slaughter at 131 kg, a summary of 13 farms averaged over 437 pigs.

SOURCE: K. Prusa et al., 'Influence of Porcine Somatotropin (pST) on Carcass Characteristics of Pigs—A Summary of 15 Producer Trials," *Journal of Animal Science 69:344, 1991.*

sponses were found to vary from study to study. In general the trials utilized 20 ppm of ractopamine and at least 15 percent protein in the diet, and all experiments were based on starting weight of approximately 60 kg and ending weights of 105 kg body weight. Averaged over all trials, ractopamine increased average daily gain by 8.4 percent and feed efficiency by 12.7 percent when compared with control pigs. Research of Veenhuizen et al. (67) and Anderson et al. (1) shows feeding beta-agonists increases growth rate and feed efficiency, decreases backfat, and increases loin muscle size of pigs.

The use of ractopamine also has a positive effect on carcass characteristics. Backfat was decreased by 15.3 percent, loin eye area increased by 16.3 percent, and muscle mass increased by 9.3 percent. In general, carcass percent lean increased from 51 percent to 57 percent when 20 ppm of ractopamine were administered (69). When lower levels were administered, response rates were lower. Similarly to pST, ractopamine increases the weight and percentage yield of trimmed wholesale cuts (ham, 7 percent; loin, 6 percent) (36).

In contrast to pST, ractopamine increased carcass yield by 1.35 percent; and beta-agonist use did not significantly reduce the amount of intramuscular fat in lean tissue. Animals fed cimaterol (68) or ractopamine (36) had the same intramuscular fat contents in their loin muscle as control pigs. Lee et al. (33) found that ractopamine feeding had only a minor effect on fatty acid profiles in adipose tissues of finishing pigs, and Walker et al. (68) found no differences due to cimaterol treatment in the total saturated-unsaturated fatty acid ratio of the subcutaneous fat. These researchers also reported that cimaterol had no affect on carcass fat firmness scores or intramuscular fatty acid profiles.

Little information about the sensory quality of pork from beta-agonist-supplemented pigs is available. Greater Warner-Bratzler shear values (toughness) of the loin increased in pigs that received cimaterol treatment in the range of 0.50 to 1.0 mg/kg (28, 68). Effects of beta-agonists on pork quality may be compound specific (36) because ractopamine feeding had no effects on the tenderness, juiciness, or flavor of fresh or cured pork.

In summary, pST and beta-agonist administration improves feed efficiency and average daily gain reduces

Table 14-4-Effect of Porcine Somatotropin (pST) Administration on Carcass Grades at a Major Commercial Packer

Commercial grades[a]	Control/109 kg Number of pigs	(percent total	PST/109 kg Number of pigs	(percent total)	pST/131 kg Number of pigs	(percent total)
No.	80	(18)	117	(41)	295	(69)
No. 2	115	(26)	83	(29)	76	(18)
No. 3	142	(32)	65	(23)	39	(9)
No, 4	76	(17)	15	(5)	11	(3)
No. 5	34	(8)	2	(1)	4	(1)
Total	447		282		425	

[a]Commercial packer grades based on live weight and tenth rib backfat thickness:

No. 1 = 0.80 in. or less (95-113 kg); 1.00 in. or less (1 14–122 kg); 1.20 in. or less (123 kg and up)
No. 2 = 0.81-1.00 in. (95-113 kg); 1.01-1.20 in. (1 14-122 kg); 1.21-1.40 in. (123 kg and up)
No. 3 = 1.01–1.20 in. (95-113 kg); 1.21–1.40 in. (1 14-122 kg); 1.41-1.60 in. (123 kg and up)
No. 4 = 1.21-1.40 in. (95-113 kg); 1.41-1.60 in. (114-122 kg); 1.61-1.60 in. (123 kg and up)
No. 5 = Over 1.40 in. (95-113 kg); over 1.60 in. (114–122 kg); over 1.80 in. (123 kg and up)
NOTE: Percents may not add to 100 because of rounding.

SOURCE: K. Prusa et al., "Influence of Porcine Somatotropin (PST) on Carcass Characteristics of Pigs—A Summary of 15 Producer Trials," *Journal of Animal Science 69:344, 1991.*

backfat thickness, and increases the carcass percent lean and the weight of the major boneless pork cuts. Carcass dressing percentage increases with beta-agonist use, but decreases with pST administration. Both growth promotants show promise as methods to produce leaner pork cuts more efficiently. These changes have implications for present pork carcass grading and payment systems.

Potential Parameters for Alternative Grading System

USDA grades and grading criteria are rapidly becoming irrelevant for at least two reasons. First, the industry does not use USDA grades because they do not measure characteristics deemed important by industry. Second, advancing technologies, such as pST, will significantly change the composition of pork cuts to leaner products desired by consumers. Current USDA grading criteria based on backfat thickness and degree of muscling will not be relevant since there will be little, if any, difference in these characteristics among products produced with the new technology. For a grading system to be useful new criteria will be needed.

In determining potential criteria for use in alternative grading systems, it seems logical to focus on those characteristics considered most important by the ultimate consumer of pork products, with some consideration of the intermediate customer and the pork processor. The goal of an evaluation scheme as it pertains to pork quality is to predict from characteristics of fresh meat the general merit and value of the cooked product. In purchasing high-value products, consumers will consider price as well as such product characteristics as amount of lean versus fat and bone in the pork product; cholesterol levels; flavor, tenderness, texture, and firmness; degree of marbling; juiciness; color of the lean and fat; and aroma of the product. Moisture holding capacity is important for products to be cured or smoked.

External Fat

Both USDA and packer grades of pork are influenced largely by the amount of subcutaneous (external) fat, which accounts for approximately 70 percent of total carcass fat (8). Until recently, external fat was trimmed to approximately ¼ inch on pork cuts at the retail level. The Pork Market Basket Study completed in 1990 at the University of Wisconsin revealed that pork currently is trimmed to an average of only 1/8 in. of external fat.

Although trimming away undesirable external fat is one method of improving product quality and increasing consumer appeal, it is less appealing to the retailer who suffers the trim loss. Fat is perhaps viewed even less favorably by the producer who stood the consequences of inefficient gains of his animals (fat requires more calories than lean). Furthermore, carcasses with excessive external fat are likely to contain more intermuscular or seam fat, which is difficult to locate and remove, particularly in large roasts. Intermuscular or seam fat levels in excess of 20 percent are common in pigs; on average that type of fat represents 15 percent of carcass weight. Thus, trimming away of external fat deposits is a less than satisfactory solution to the fatness issue.

Photo credit: John Forrest, Purdue University

Grades for pork carcasses are based on a combination of subjective visual appearance and measurement of fat thickness (by simple ruler) and carcass weight. Fat thickness will not be a relevant criteria in the future.

Lean-Fat Ratios

An accurate method of determining directly the total fat percentage or lean-fat ratio of carcass products would be valuable for both consumers and packers. Present measurement procedures will be described in a later section. These techniques do not adapt well to the modern-day rapid slaughter line. The Anyl-Ray procedure for assessing fat content of ground fresh meat samples is widely used in meat processing and has a relatively high degree of accuracy; however, it cannot assess fat content of the intact carcass.

Intramuscular Fat

The relative importance of marbling (intramuscular fat) to product acceptability is not clearly established. Malphrus et al., (34) reported a closer relationship between marbling and juiciness than between marbling and tenderness, although both exhibit a positive relationship. Further, marbling seems to be more important to palatability in fresh than cured pork and more important in chops than in pork roasts. However, marbling or intramuscular fat generally is considered a factor affecting palatability (7, 11, 53).

Cholesterol and Unsaturated Fatty Acids

Reduction of caloric content (fat content) of meat can contribute to reduction of obesity in humans and possibly improved health. The fat component of meat (particularly saturated fatty acids and cholesterol content) has been implicated in cardiovascular disease (23). More recently, red meat consumption has been linked to higher rates of colon cancer.

Muscle Quality

Problems of poor muscle quality continue to plague the pork industry. Pale, soft, and exudative (PSE) and dark, firm, and dry (DFD) muscle have been reported for 3 to 25 percent of carcasses in U.S. packing plants. Exudative pork has the tendency to lose water. It is important to monitor this problem if our foreign markets (particularly that of color-conscious Japan) and our domestic market are to be maintained or expanded.

Tenderness

Objective muscle shear measurements such as the Warner-Bratzler shear have been positively correlated with palatability (tenderness) of cooked pork as well as other meats (7). While there may not be a practical approach to obtaining this measurement on fresh carcasses, there may be a need to include some measure of tenderness in the grading process. In Denmark, shear force values have increased significantly with reduction in backfat and increased lean content. These changes have been significantly associated with a reduction in intramuscular fat. To date, there is no practical direct method of evaluating tenderness in fresh meat or in the meat animal carcass. Indirect indicators of meat tenderness such as color and texture of lean are questionable, at best.

Nutrient Content

Nutrient content variation in pork cuts with a similar lean-fat ratio primarily reflects the PSE condition and the extent to which nutrient-containing juices are exuded. For example, many nutritional elements are water soluble and may be lost during retail storage or cooking. Meyer et al. (37) examined B vitamin content and found greater losses from PSE muscle than from normal muscle. Niacin, however, was found to be higher in the final cooked PSE muscle. Biochemical differences in muscle metabolism were postulated as the reason for these differences. Collection and analysis of the drip from normal and PSE chops showed losses of protein, potassium, calcium, and magnesium per unit weight of lean were higher in PSE chops (16). Nutrient concentration of the drip was similar for the PSE and normal chops, but twice as much drip from PSE chops meant greater nutrient losses from the PSE product. Such losses, however, represent a very small portion of total nutrients present in a pork chop, and the differences observed did not appreciably change the nutritive value of PSE chops.

Flavor

Flavor is the most difficult to define of all the sensory traits. The lipid composition and metabolism of fat primarily are responsible for flavor (56). However, lean is also known to have important flavor components (9). Minimum quantities of fat necessary for "typical" flavor are not clearly defined, perhaps because juiciness becomes a palatability factor at low fat levels before loss of flavor occurs. The lipid component of pork can lead to the development of off-flavors. The high degree of unsaturated fatty acids in pork fat is the major reason for the potentially greater rancidity of pork relative to beef. There are no commercially feasible technologies currently available for measuring flavor. The primary technique utilized presently is sensory panels.

Options for an Improved Grading System

There are a number of alternatives to the current USDA pork grading system that warrant consideration. A few observations about the current situation and imminent changes in the pork industry will lay the background for consideration of possible changes in the pork grading systems. The current USDA pork grading system is not effectively differentiating between carcasses that vary widely in value. Packers are not currently using the USDA grading system for evaluating or pricing hogs. The packer grading systems in use vary in the extent to which they differ from the USDA system. The inadequacy of the USDA grading system will become more apparent as producers begin using new growth promotant technology such as pST or beta-agonists.

Product characteristics valued by the consumer are only partially reflected in current grading systems. Fat content of pork products is a key factor for consumers, and external backfat thickness is a key factor in current packer and USDA grading systems. Fat content is related to calorie content, so calories are indirectly considered. While there currently are no grades for retail pork products, the labeling systems on a limited number of branded, processed products listing percent fat-free and calories serve the same purpose. Cholesterol and saturated fatty acid content, and muscle quality traits (color, tenderness, texture, etc.) considered important by consumers are not reflected in current grading systems. Technologies to measure these variables are not curently available or cannot be economically incorporated into the fast line speeds, etc., of the modem packing plant. (See box 14-A.)

Ideally, grading systems should provide recognizable homogeneous groups of products based on highly valued consumer characteristics that are accurately and efficiently measured. This would facilitate better informed purchasing and pricing decisions, and market feedback. Making producers and processors aware of value differences via the grading and pricing and market information system should improve industry resource allocation.

New growth promotants being developed for use in pork production are likely to change the compositional relationships within the pork carcass and the resulting consumer products. These changes will primarily impact lean/fat/bone relationships rather than sensory properties or eating quality. The compositional changes will necessitate further adjustments in current grading systems to provide accurate grading, equitable pricing, and accurate price reporting of pigs and their products or the elimination of grades altogether.

Several changes in the grading system that might improve industry performance are considered. Potential benefits and costs to consumers and industry participants are briefly analyzed.

Option l—Status Quo

Maintain the status quo in the USDA grading system, with a single measurement of backfat depth as the primary indicator of grade. This would be the least expensive alternative for the government and pork industry. Since packers currently do not use the USDA grading system, the impact on industry performance would be limited to the market information system that relies on USDA grades for price reporting. The Federal-State market price information based on USDA grades will become gradually less discriminating and useful, as an increased proportion of carcasses varying widely in value would be graded U.S. No. 1. The Federal-State Market News service has already deviated from using the USDA grading system by splitting their U.S. No. 1 grade carcass price reports into separate price reports for hogs with less than 0.8 inches of backfat and more than 0.8 inches of backfat.

Use of growth promotants will further widen the current disparity and variability between carcass grade and carcass value, especially in the highest grade. Differences between packer grading standards and USDA grading standards will likely continue to widen if packers continue to adapt their grading and evaluation systems to the changing characteristics of the market hog population. Several different packer grading and evaluation systems will continue to coexist, with differences in method and accuracy of evaluation. Producers will continue to have difficulty comparing alternative packer price quotations based on different grading systems. This would primarily affect producers' abilities to assure getting the best price for their hogs, and would have a small impact on resource allocation decisions by pork producers. Grades will continue to offer no useful information on lean quality or fat content to consumers, but individual packer grades and pricing systems likely will continue to offer some incentives for leaner hogs. However, many packer grading systems may have to be changed to reflect more accurately the changes in carcass composition from pigs produced using new growth promotants. The USDA grades will be even less able to reflect relationships between value characteristics and value. At the extreme, USDA grades could be rendered highly ineffective.

Option 2—Develop Grades Based on Lean-Fat Composition and Quality

Develop pork grades designed to reflect lean-fat composition as well as product characteristics most highly valued by the consumer. Use these grades for consumer products as well as at the packer level. Such grades might distinguish product groups differing in eating quality (tenderness, texture, freedom from PSE, freedom from odor, and color) and composition (percent lean, calories per ounce, etc.). There could be a separate quality grade, or a minimum quality standard for each composition grade.

Box 14-A—Technology To Evaluate Pork *Carcasses or* Procuts

Some 50 years **of research and development has gone** into the grading and classification of pig carcasses. Along with visual **assessment and direct measurement of various fat and lean parameters with grids and metal rulers, the industry now has several highly sophisticated electronic techniques with which to measure economically Important characteristics of pork carcasses or products. Some of these await only the final stages of development before they can be applied commercially.**

Current Technology Available for Measuring Composition of Pork Carcasses and Pork Products

Subjective Visual Assessment and Ruler/Grid Measurements

Currently, grades for pork carcasses are based on a combination of subjective visual appraisal of muscle thickness and objective measurements of fat thickness and carcass weight. In reality, most carcasses **that are graded are subjectively evaluated by trained personnel However, actual measurementt of fat thickness at some point on the midline of the split carcass often is done with a simple ruler. the correlation of 10th rib backfat depth with quantity of fat-free lean mass is generally low (-0.27), but the measure is much more highly correlated with percentage fat-free lean mass (-0.56) (42). Combining measurements of the cross-sectional area of the loin muscle at the 10th rib with measurement of fat depth at the 3/4 point over the loin muscle significantly improves the prediction of either fat-free lean mass or percentage fat-free lean mass.**

Carcass and cut Dissection

The standard to which most techniques for carcass evaluation are compared is the complete dissection of at least one side of the carcass into lean, fat, bone, and skin followed by chemical analysis of the soft tissues to calculate either a fat-free lean mass or a fat-standardized lean mass. In many instances the major primal cuts (ham, loin, belly, shoulder) are dissected individuality in order to determine changes in composition within the carcass that could be due to breed, or the utilization of growth stimulants or repartitioning agents. This is not practical in current commercial slaughter plants.

Carcass and cut Grinding and chemical Analysis

Grinding of the whole side or entire carcass followed by chemical analysis is sometimes utilized to determine composition under research conditions. while this technique reduces the labor that would be required for full dissection, it is very costly because none of the tissues can be salvaged for **human consumption. Another disadvantage of this technique is that the composition of the edible soft tissues and the skeletal** structures cannot beseperately determined. Like car**cass and cut dissecttion, this too is not practical for commercial slaughter plants.**

Photo credit John Forrest, Purdue University

The Fat-0-Meter is an optical probe that directly senses reflected light to **determine tissue boundaries.**

Optical and Mechanical Fat-Lean Probes

The Hennessy Grading Probe, Fat-o-Meter, Anatech PG-1OO, and Tecpro PG-200 are optical probes that directly sense reflected light to determine tissue boundaries. Accuracy levels of the grading probes in predicting percentage lean vary depending **on the probe sites and combinations of parameters.**

Mechanical-Pneumatic Assessmentt of Confirmation

An electro-pneumatic mechanical system measures the width of hams and loin. These measurements are combined with fat depth determined on the midline. This system is considerably more complex and expensive than an optical probe.

Potent/a/ Technology for Measuring Composition of Pork Carcasses and Pork Products

Magnetic Resonance Imaging and Nuclear Magnetic Resonace Spectroscopy

Magnetic resonance imaging (MRI) utilizes electromagnetic signals induced by a strong magnetic field to map and image fat and lean tissues. This technology is currently very expensive to purchase ($225,000 or more) and requires special shielding. It is slow and not currently adaptable to modem day slaughter plants. The high correlations with lipid (0.965), water (0.995) and protein (0.995) content from MR spectroscopy and the high resolution obtained from MRI images suggest that this technology could be used in research to replace time consuming and expensive carcass dissection. **To be effective in commercial application, further research and development to reduce the cost and increase the speed of operation would be required.**

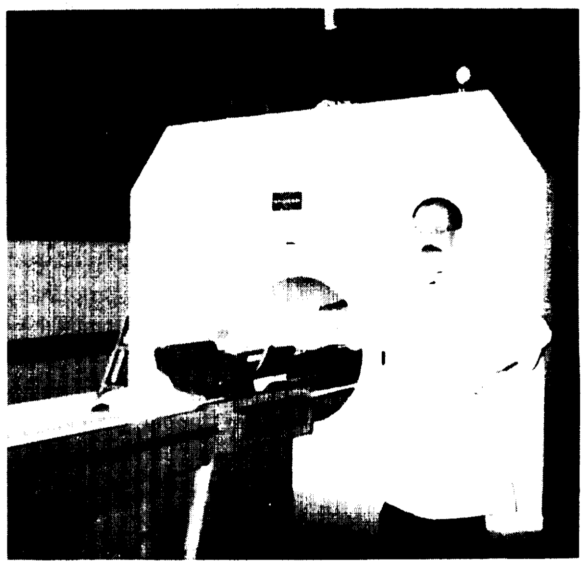


Photo credit: John Freest, Purdue University

Magnetic Resonance Imaging is a potential technology for measuring pork carcass composition by **using electromagnetic signals to map and image** fat and lean tissue.

x-ray computed Tomography

CAT scan or X-ray Computed Tomography produces a two-dimensional cross-sectional image of the carcass. A CAT scan of live animals has been shown to give highly accurate predictions of pork carcass composition without significant biases with respect to gender, breed, or live weight (55). The Norwegian Meat Marketing Board plans to use this technology to replace carcass dissection **in the validation of other** live animal and carcass grading instruments. High cost and the slow rate of data capture make this technology currently impractical for consideration **in online applications.**

Video Image Analysis of Conformation and Fat Depth

Video image analysis offers the possibility of objectively measuring the shape and thickness of pork carcasses, and could be combined with lean-fat probe data to improve predictive accuracy. In Denmark, a classification center has been developed for beef carcasses that uses video image analysis combined with an optical probe system. Tecpro, a company in Germany, is developing a similar system for pork carcasses. Costs for this system are difficult to determine at this point. Speed of operation should be limited only by computer capability for image processing.

Bioimpedance Analysis

Bioimpedance analysis (BIA) exploits the conductivity differential between the fat-free mass and fat to measure carcass fatness. As carcass fatness increases, the impedance to the flow of electricity increases. BIA has been shown highly accurate in predicting the fat-free soft tissue content of lamb caresses (27). Swantek and coworkers (61) reported that BIA accounted for 64 percent of the variation in fat-free mass in chilled pork carcasses. This system, as currently structured, would be difficlt to use in the context of current line speeds of many packing plants.

Ultrasound

Real-time ultrasonic imaging devices have the ability to produce cross-sectional images at various locations in either the live animal or carcass. An **image of the cross-section of the loin at the 10th rib can be used to obtain measurements of fat depth and loin muscle area. From this a model can be developed to estimate either the weight or percentage fat standardized lean mass. This technique may be useful in evaluating composition of seedstock animals or for evaluation of market animals to determine optimal market weight. With proper engineering and adaptation, ultrasound also may be useful in evaluating carcasses on the slaughter line.**

SOURCE: Office of Technology Assessment, 1992.

Including eating quality characteristics as grading criteria could make the pork grading system more useful at the consumer level. Unfortunately, few such characteristics are amenable to reasonably accurate and efficient measurement under commercial conditions. And it is not clear what quality measures would reflect characteristics consumers consider important but cannot visually evaluate themselves.

The cost and difficulty of implementing composition or quality grades beyond percent lean in ground pork might be particularly oppressive for small processors or retailers who do a small amount of meat processing. Mandatory label or grade information thus could have some undesirable structural implications. On the other hand, providing that information could level the playing field between small processors and larger retailers and processors with advertised brands. Further, reducing consumer uncertainty regarding any important quality characteristics by having a grade carry through to the consumer level could enhance consumer demand for pork products, and provide signals regarding undesirable quality to hog producers and pork merchandisers, which could stimulate quality improvements.

The technical feasibility of quality grading is a critical issue. Without a clear, pressing quality problem adversely affecting domestic or export demand, the potential benefits may not be large enough to justify this option even if the technical problems could be overcome. The price reporting system necessarily would become more complex as quality and composition differences would have to be reflected in price reports, requiring significant administrative costs and education of marketing system participants.

Option 3—Require Standardized Grading and Measurement Systems

Require packers to use standardized grading systems and a standardized effective measurement technology. Use that system for market price reporting.

This would be unpalatable for packers who usually are extremely independent and negative toward more government intervention in their operations. Standardized grading systems would make price reporting easier and more accurate, and facilitate comparisons of grade-related packer bids or hog prices for producers. However, this approach would not allow individual packers to adjust to any special considerations relevant to their customers or suppliers. Moreover, USDA grading systems have been notoriously slow to change when conditions warranted it, and the same might be true of any standard grading system. Small packers may find it difficult to compete if needed changes are expensive to implement.

Greater equity among producers may be facilitated by these changes. Other economic benefits are in the form of faster industry adjustment to consumer wishes and improved resource allocation and efficiency in the long run. The costs would be incurred in the short run, primarily by packers (especially small packers) and producers of “poor quality” hogs. Establishing a mandatory system would involve significant research and development costs by the USDA and packers (and subsequent processors and merchandisers of pork products if the quality and composition grades would be carried through to the consumer level). The added operating costs could also be significant. Standardization across all packers and merchandisers would certainly improve the accuracy and ease of acquiring price reports related to the USDA grading system, but the complexity of the system would also be increased significantly.

Option 4—Use Percent Lean as USDA Grade Criteria

More extensive use of lean-fat probes to predict carcass lean percent suggests that percent lean (based on loin muscle depth and backfat thickness, off-midline) rather than the current percent-lean cuts (primarily based on midline backfat thickness) is a grading criterion more in tune with the measurement technology becoming dominant in the pork industry. If the USDA simply based grades on percent lean without tying particular backfat or loin depth measures to any numerical grades (e. g., 52 to 53 percent lean rather than U.S. No. 1) the grade relationships would be less apt to lag behind changes in the hog population.

The percent-lean measure, which is the common standard for carcass evaluation by meat scientists today, has one flaw. It does not reflect the fact that lean from a loin or ham has a different market value than lean from another part of the animal. If the hog population has significant variability in the proportion of carcass lean coming from various parts of the animal, those differences in value would not be accounted for in a grading and pricing system based on (total) percent lean.

However, this system might be superior in value discrimination to some packer systems now in use, and would be compatible with the probe technology currently used by several large packers. Further, the percent-lean criterion at the carcass level would be consistent with the lean-fat composition information that many consumers demand for pork products.

Significant administrative costs would be required to establish new grades and to implement the price reporting system. Price reporting might be difficult for packers not using probes, but current measurement systems could be adapted to the percent-lean criterion. If slightly less accuracy in grade reporting is acceptable, it probably would not be necessary to require use of probes for this system to be workable. If probes were required, this would involve significant transition costs for many packers.

Option 5—Abolish the USDA Pork Grading System, and Use Percent-Lean Descriptive Terms for Classes of Market Hogs in Government Price Reporting

Currently, the USDA grading system is used only by the Federal-State Market News Service in providing the market classes for price reporters to use. Many packers already are using the percent carcass lean as their basis for market hog grading and evaluation; others have not adopted that system, often because of perceived problems with the probe measurement system or because their own system is considered adequate. Asking packers to shift to a new USDA grading system would involve significant transition costs to packers not using a percent-lean probe system, and more market costs for packers currently using those systems. If packers do not use USDA grades now in their grading and evaluating systems, a high likelihood exists that they would continue to use their own systems, which they have tailored to their specific needs, even if the USDA system was improved. In addition, USDA grades require significant time and administrative costs to promulgate, and may in the future lag behind practices used in the industry. These costs can be avoided by eliminating official grades. Instead, prevalent industry terminology (weight and percent-lean classes) could be used to report prices by government price reporting agencies, in consultation with the users of the price reports. This could be done with much less administrative cost, and retain greater flexibility to change with industry practices and technology. Since many hog producers may not be familiar with the percent-lean terminology, price reporters could use percent-lean ranges *and* corresponding backfat ranges with which farmers are familiar in price reporting for a transition period.

The benefits of this system would be the lower cost and greater adaptability to changes in the market hog population and measurement technologies, due to reduced bureaucracy involvement; and a better basis for government price reporting. It would encourage the movement by many packers to have their prices more accurately reflect carcass merit. The costs would include those necessary for government agencies to develop comparable percent-lean and backfat measurements for use in translating prices paid on the basis of nonconforming grading systems into prices for the percent-lean equivalent classes. Also, the lack of uniformity of packer grading and evaluation systems would continue, with attendant problems for producers in comparing packer bids based on different systems. However, the increased use of percent-lean systems should gradually lead to easier comparisons.

Conclusions

Many packers are shifting to probe measurement systems where their grades and prices are based on estimates of carcass lean percentages. Since these estimates are not based solely on backfat, the USDA could shift to carcass lean percentage as the basis for both grade and price reporting. However, it does not seem likely that such a change will prompt many pork slaughter processors to adopt the USDA grading system, since many of them have their own system already developed and adapted to their needs. Moreover, changing internal evaluation systems is costly.

Grading or labeling the quality of lean would appear desirable in pork products and carcasses. However, this seems impractical at this time due to the absence of commercially feasible measurement technology. Nutrient composition or similar labeling of fat content, calories, fatty acid profiles, or cholesterol content for pork products at the consumer level would provide information that could enhance demand or provide clearer signals to producers and processors regarding consumer preferences. Some branded pork processors currently are providing some of this information. In addition, some industry consumer information programs are beginning to move in this direction. Unfortunately, the commercially available technology for meat-quality evaluation is primarily adaptable to ground meat, and fat content is more easily measured than some other characteristics. Adapting this approach to highly variable intact fresh and processed pork products could add relatively significant capital and labor costs, especially in small processing and merchandising operations. If effective quality measurement technology were developed, the quality measurements and information provided would need to be incorporated into product evaluation and pricing throughout the marketing system. Then, consumer reactions to differences in quality would be effectively transmitted through the system and affect prices paid to producers.

Several promising technologies that might provide accurate estimates of lean/fat composition of carcasses or pork products, including products affected by the new growth promotants, are in the research and development stage. This research could be encouraged. These technologies, when commercially feasible, could be incorporated with grading programs that focus on carcass percent lean. Classifying pork carcasses via carcass lean percentages could be initiated with the view toward adding lean-quality information at a later date. When a commercially feasible lean-quality measurement becomes available, pork carcass grades could be determined by carcass percentage lean and quality of the lean. Dramatic adjustments in reporting of pork prices would not be needed to incorporate quality information with carcass percent-lean information.

Finally, the descriptive terms (currently primarily USDA grades) used in government price reporting could be changed to percent-lean classes, with related backfat measures reported for a transition period. In the longer term, quality information can be added when commercially feasible. When fully implemented, price would be reported by percent-lean and lean-quality classes or measurements. If there is a need for a USDA grading system, it could be based on carcass percent lean, measurements (not grades), with lean-quality information added when it becomes commercially feasible to do so. However, packers are unlikely to use an improved voluntary system. Price reporting agencies should be able to adopt percent-lean ranges for reporting prices with less bureaucratic cost and more flexibility than would be the case for changes of grading systems. Consequently, a strong argument can be made for abolishing the USDA pork grading system. This is essentially what has been happening de-facto in the pork industry over the last decade.

THE FRUIT AND VEGETABLE GRADING SYSTEM[2]

The U.S. Department of Agriculture has a long-established system for fruit and vegetable grades. Standards used to determine a grade include “attributes,” such as size, quality, and condition, and their related “tolerances. ” For example, one attribute for fresh market potatoes is “free from sunscald. ” The tolerance for this attribute is “no more than 10 percent defects at the point of shipping. ” This attribute and its tolerance are used along with other attributes and tolerances to designate grade. Attributes are based on sensory characteristics, such as touch, sight, and taste, as well as shelf-life considerations, palatability considerations, or some combination of these factors.

Challenges have been raised to the Federal grading system. Some question grades that do not explicitly include health and nutritional factors. Others argue that the current sensory-based grade attributes indirectly encourage the use of chemicals in production, so as to minimize blemishes and ensure vibrant skin-color.

Consumers are increasingly concerned about the use of chemicals or chemically based ingredients in the production and preservation of our food supply, both for environmental and health reasons. There is concern that chemicals used in the production process may damage the environment and that chemical ingredients in or on food may impair human health, perhaps in ways yet unknown to the scientific community.

Consumers increasingly want to be more fully informed about choices available in the marketplace. Given such information consumers will, through their purchases, indicate levels of nutrition they want, what levels of pesticide residue they are willing to tolerate, and what level of blemishes they are willing to accept.

Thus, some alternative or revised set of grade attributes might be more socially desirable than current sensory-based attributes. The natural question that arises is whether it is more feasible and desirable to incorporate additional or modified attributes, such as nutrition information or other “nonsensory “ information, into current standards; or to identify conceptual alternatives to the current sensory-based standards. This case study focuses on the use of sensory and potential alternative grading attributes for fruits and vegetables.

Fruit and Vegetable Production and Consumption

The U.S. fruit and vegetable industry accounts for 8.7 percent of the market value of all agricultural products sold in the United States (table 14-5). Fruits, nuts, and berries account for 5.2 percent of the market value whereas vegetables account for 3.5 percent of the market value. Reflecting their high market value per acre of production, fruits, nuts, berries, and vegetables account for only 1.8 percent of total U.S. acreage.

[2] This analysis is based on the OTA commissioned paper ''Assessing Federat Grade Criteria for Fruits and Vegetables, " by Thomas Sporleder, Rebecca Boerger, Mark Bennett, James Hoskins, Eugene Jones, Timothy Rhodus, Kurt Wiese, and Carl Zulauf, all associated with the Ohio State University (59).

Table 14-5—Market Value of Agricultural Products Sold and Total Acreage, United States, 1987

	U.S. total	Total fruits, nuts and berries	% of total	Vegetables	% of total
Market value of agricultural products sold ($1 ,000)	136,048,516	7,084,818	5.2	4,698,083	3.5
Acreage (acres)	282,223,880	4,404,946	1.56	3,467,563	1.23

SOURCES: 1987 Census *of Agriculture AC87-A-51,* U.S. Department of Commerce, Bureau of the Census, November 1989 and *Fruits and Nuts Situation and Outlook Report Yearbook,* U.S. Department of Agriculture, Economic Research Service, Washington, DC, November 1990,

Table 14-8-Top 12 Commercial Shipping Point Commodities, Fresh Inspected Shipments, Fiscal Year 1990
(Reported in cwt.)[a]

Commodity	Tonnage
Potatoes	100,805,477
Tomatoes	25,645,867
Apples	19,313,891
Onions	15,667,916
Grapefruit	13,628,587
Grapes	9,166,998
Oranges	7,976,860
Cantaloupes	7,483,463
Pears	6,790,235
Lettuce	6,751,039
Peaches	6,071,965
Plums	5,179,140

[a]Inspected fresh product only.

SOURCE: Fresh Products Branch, Annual *Report for Fiscal Year 1990,* AMS, U.S. Department of Agriculture, Washington, DC, 1990, and "Fruit and Vegetable Shipments:Market News, AMS, USDA.

Table 14-7—Number and Type of USDA Grades for Fruits and Vegetables

Category	Number of grade standards
Fruits for fresh market:	
Wholesale market	29
Raw products for processing	15
Fruits for processing	15
Canned fruits	36
Dried and dehydrated fruit	14
Frozen fruits	21
Vegetables for fresh market:	
Wholesale market	58
Consumer retail market	12
Vegetables for processing	24
Canned vegetables	39
Frozen vegetable	26

SOURCE: U.S. Department of Agriculture, Agricultural Marketing Service

In terms of tonnage at commercial shipping points, the most significant commodity among fruits and vegetables for fiscal year 1990 was potatoes (table 14-6). Tomatoes were second in volume but with only about one-fourth the volume of potatoes. Apples were the third largest commodity volume-wise with about three-fourths the volume of tomatoes.

Apples, oranges, potatoes, and tomatoes were chosen here for specific case analysis. These commodities were selected because they represent a wide variety of grade standards, have relatively high per capita consumption, and figure significantly in today's food markets. Annual value of production for these commodities ranges from $1 billion for apples to nearly $3 billion for potatoes. Annual consumption per capita for the four commodities ranges from about 15 pounds for oranges to over 127 pounds for potatoes. Since 1970, per capita consumption of all fruits and vegetables in the United States has trended upward.

USDA Grade Standards

Current grade standards for fruits and vegetables are administered by the U.S. Department of Agriculture (USDA) under authority of *The Agricultural Marketing Act of 1946.* The purpose of these sensory-based grade standards is to encourage uniformity and consistency in commercial practices related to the quality, quantity, and condition of agricultural products shipped in interstate commerce.

Use of USDA grade standards is voluntary. However, if a firm decides to use grade standards and designate the U.S. grade on a package label, they must use USDA's grade standards.

Fruit and vegetable USDA standards can be grouped into categories (table 14-7). Most grade standards for fresh fruit and vegetables pre-date 1960. Grade standards for processed fruit and vegetables generally are of more recent vintage.

At the commercial shipping point nearly 90 percent of fresh potatoes and approximately 77 percent of fresh

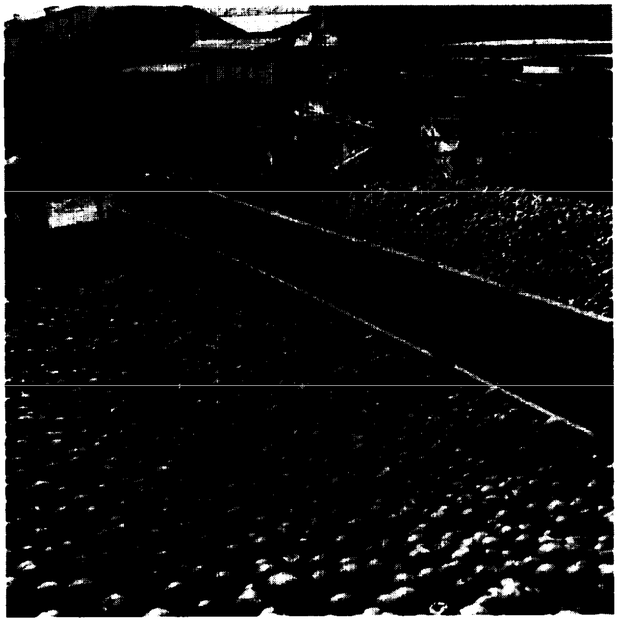


Photo credit: Grant Heilman, Inc.

Voluntary sensory-based grades encourage uniformity and consistence of agricultural products. At least 75 percent of fresh tomatoes are graded.

tomatoes are graded. Only about one-third of fresh apples and around one-fifth of the fresh oranges are graded.

At the raw product processing stage, nearly 80 percent of potatoes were graded while only about 5 percent of the tomatoes were graded. Approximately 86 percent of the oranges and nearly 30 percent of apples are graded.

Grading attributes can be broadly divided into three categories: size, quality, and condition. Size of a commodity can be described by diameter, length, weight, and uniformity (65). Quality factors are defined as "the combination of the inherent properties or attributes of a product which determines its relative degree of excellence" (26). In general, quality factors refer to the attributes of a commodity that remain permanent once the commodity is harvested. Examples include variety, cleanliness, shape, and maturity. Defects in quality can be divided into four classes:

1. fungal injuries,
2. insect injuries,
3. mechanical injuries, and
4. other defects (ill shaped, undesirable color, sunburn, growth cracks, and dirt) (65).

Condition refers to

> the relative degree of soundness of a product that may affect its merchantability and includes those factors that are subject to change after harvest. Condition (i.e., ripeness or freshness) may reflect age, improper handling, storage or lack of refrigeration. . . . (10).

Along with attributes, tolerances are used to determine grade. Tolerances are legal limits of acceptable size, quality, and condition attributes. They generally are stated in percentage terms, and can vary by product, use, or size of the individually packaged product. The tolerances for U.S. No. 1 apples illustrate the variety of forms that tolerances can take:

1. no more than 10 percent of apples with quality and condition defects including no more than 2 percent of apples with decay, 2 percent with internal breakdown and 5 percent with wormholes; and
2. the apples cannot be further advanced in maturity than generally firm ripe.

Size, quality, and condition attributes, as well as tolerances, differ for different commodities, they also vary with market destination. In general, attributes and tolerances are more strict for fresh produce destined for the fresh market than for fresh produce destined for the processing market. For example, U.S. Extra No. 1 fresh potatoes at the wholesale level must be firm, a condition attribute. In contrast, U.S. No. 1 potatoes for processing at the wholesale level have a comparable condition attribute of moderately firm. Similarly, the retail consumer grade for fresh produce tends to be more strict than the wholesale standard, To illustrate, for U.S. No, 1 tomatoes at the wholesale level, defects can total no more than 10 percent at shipping points or no more than 15 percent en route or at the destination point. On the other hand, defects can total no more than 5 percent for U.S. Grade A fresh tomatoes at the consumer retail level.

Most sensory attributes are measured by inspectors using their sense of touch, sight, and smell. Many technologies, however, have been developed to measure sensory attributes of foods. A considerable amount of automation and computerization is occurring in this area. For example, up-to-date mechanical harvesters used in the harvest of processing tomatoes are computer equipped and give a preliminary objective color assessment that is more accurate than previous human, subjective evaluation. Advancements in computer technology are leading to fully automated color and size measurements that will permit accurate sensory evaluation of products from the field to the retail store, with perhaps the need for only limited human spot-checking (38). One large fruit pack-

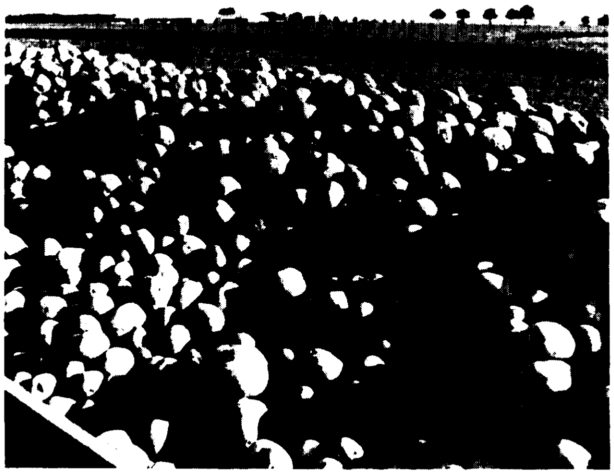


Photo credit: Grant Heilman, Inc.

Most sensory attributes are measured by inspectors using their sense of touch, sight, and smell. Inspectors grade nearly 90 percent of all fresh potatoes.

ing house in Florida recently added computerized equipment that weighed, optically scanned for dimensions, and used an infrared camera to determine fruit size. Used together, the processes are able to determine density and cull fruit that is internally damaged by freezing (63).

Conceptual Considerations of Grade Standards

A grade is assigned to fruits and vegetables by applying prespecified standards to a random sample of the commodity being graded. Three conditions must be met for an attribute to serve as a grade standard. First, the quality, condition, and size attributes stated in the standards must be observable or measurable. If an attribute cannot be observed or measured, then it is not possible to include it in a grading standard. Second, information about the attribute must exist and be available to the public.

Third, the attribute must vary among individual specimens of the commodity. If the attribute does not vary, then including it in the grading standard would provide no information. The use of tolerances on quality, condition, and size attributes reflects this variability. Tolerances allow for a sample to obtain a given grade even though not all specimens in the sample have the same quality, condition, and size attributes.

Basing grades on the presence and quantity of chemical residues and nutrient value, for example, mandates knowledge about chemical residues and nutrient values. If these two attributes vary among samples of a commodity, and are measurable, they can be incorporated into or substituted for existing grade standards. The next two sections address the measurement and variability of nutrient and chemical residue attributes in fruits and vegetables. Their purpose is to introduce the conceptual basis for two different fruit and vegetable grade standards—one based on nutritional content, the other on chemical residues.

Nutritional Attribute Measurement

Cost-effective techniques that provide information on a timely basis do exist for several nutrients (box 14-B). The willingness of consumers to pay for this information could broaden the range of cost-effective techniques for nutrient analysis. An alternative approach is to determine if sensory characteristics also convey information about nutritional characteristics. In other words, can sensory grade attributes be used to evaluate the nutritional characteristics of fruits and vegetables? This question is addressed in the next section.

Nutritional Attriutes Variation

Knowledge Gaps

While much is known about the nutritional value of fruits and vegetables, inadequate data exist in many key areas **(3).** (See tables 14-8 and 14-9.) Little or no data exist for 9 nutritional components of fresh fruits, 14 nutritional components of frozen or canned fruits, 18 nutritional components of fresh vegetables, and 12 nutritional components of frozen and canned vegetables. This lack of information is due in part to the minute quantities of some nutritional components of fruits and vegetables, and uncertainty as to the exact nature of these components' contribution to human nutrition. For example, the fat soluble vitamins (A,D,E, and K) can be accurately assayed and quantified in most samples. However, quantities of these vitamins may be present in bound form or other forms not utilizable or under-utilized in human physiological processes. Thus, their overall role in human nutrition is uncertain. Additional research on nutrition of fruits and vegetables is needed before all nutritional attributes can be included in a grading standard.

B0X 14-B-Technology for Nutrient Attribute Measurement of Fruits and Vegetables

Nutritional attribute of food in general cannot directly be sensed by consumers. Consequently, scientific methods and instruments are needed to measure these attributes. Currently available methods and instruments are numerous and sophisticated.

Currrent Methods for Determining Nutrient Content

In addition to water, fruits and vegetables usually contain significant amounts of most or all types of carbohydrates, such as sugars, starches, and fiber. They also contain vitamins (notably vitamins A and C) and smaller, but nutritionally significant, amounts of minerals and protein. Specific methods of analysis exist for each nutrient category. These methods have varying degrees of accuracy, simplicity, and cost.

For carbohydrates, analytical methods indclude observing color changes, microbial assays, enzymatic assays, and chromatography. Chemical extraction procedures will use one of these methods to extract and differentiate simple sugars, complex sugars, starch, and dietary fiber for analysis. A technique recently developed for quantifying fiber is enzymatic degradation.

Protein composition generally is determined by empirical techniques. Proteins are decomposed into constituent amino acids by hydrolysis (a decomposition procedure using water). These amino acids are isolated by chromatography (a technical procedure that separates substances based on factors of size, electrical charge, or affinity for another compound).

Analysis of mineral components in plants is challenging because minerals generally are present only in minute quantities. Traditionally, quantification of mineral has involved analysis of the inorganic ash residue obtained from burning a plant sample. Mineral ash from fresh fruits ranges from 0.2 to 0.8 percent of the weight of the entire fruit, and the quantity of ash generally is inversely related to moisture content. Mineral content in vegetables is usually higher, at about 1 percent. The oldest analytical techniques applied to mineral ash forms of spectroscopy (xray fluorescence absorption.) Spectroscopy is the observation and measurement of radiation emitted from chemical elements after their atoms have been excited in a certain way. Each element has a characteristic pattern of wavelengths following excitation (45).

Assessment of *Current Techniques* and Methods

Beecher and Vanderslice have cattegorized methods of nutrient analysis based on their level of accuracy and other attributes as adequate, substantial, conflicting, and lacking. Their criterion for accuracy is the production of an analytical value within 10 percent of a true value when a nutrient is presentn food at a nutritionally significant level, defined as greater than 5 percent of the Recommended Daily Allowance (RDA) per standard serving or daily intake, whichever is greater. Many methods fail to meet this criterion (45).

Adequate and "substantial" methods are highly accurate, Speedy, and modest in cost-defined as less than $100 per test. "Conflicting" and "lacking" methodologies are unlikely to render valid results under conditions of routine analysis.

Although problems exist with accurate assessment of nutritional components of fresh fruits and vegetables, analysis of fresh produce is less Problematic than is analysis of processed foods. Adequate and substantial methods of analysis already exist for many nutrients in fresh fruits and vegetables.

Developments in Nutrient Composition Measurement

Technological advances are improving the ability to accurately and expeditiously measure nutrient components. An example is flow injection chromatography (60). it permits numerous rapid sequential analyses and is appropriate for constituents other than proteins, including vitamins, and carbohydrates. Similarly, a new advance in spectroscopic analysis is Simultaneous Multielement Atomic Absorption Spectrometry (SIMAAC). It is a furnace atomization technique that compares analytic signals to known calibration standards. Simultaneous Muitielement Atomic Absorption Spectrometry, which permits simultaneous analysis of up to 16 elements, has important implications for more rapid sample turnout in nutrient analysis of foods. However, careful sample preparation and accurate instrument calibration is required to avoid erroneous results (60).

Other new techniques in food analysis Include use of bioindicators, mass spectroscopy, delayed light emission, xray diffraction, supercritical $C0_2$ chromatography, microbial assays, and computerization. Although the list is not all inclusive, it suggests some of the directions food analysis will follow. Last, advances in computer technology point toward further miniaturization of techniques as well as improved speed and accuracy.

SOURCE: Office of Technology Assessment, 1992.

Table 14-8-Knowledge of Nutrient Composition of Fresh Fruits

Nutritional component	Little or no data	Substantial data	Inadequate data	Not applicable
Individual sugars		x		
Starch	x			
Nutrient fiber			x	
Total fat		x		
Fatty acids			x	
Sterols			x	
Calcium		x		
Iron		x		
Phosphorous		x		
Sodium		x		
Magnesium		x		
Potassium		x		
Zinc		x		
Total protein		x		
Individual amino acids			x	
Folacin			x	
Vitamin D				
Vitamin E		x		
Biotin	X			
Choline			x	
Pantothenic acid			x	
Vitamin A		x		
Vitamin B1 (Thiamin)		x		
Vitamin B2 (Riboflavin)		x		
Vitamin B6		x		
Vitamin B12				x
Vitamin C		x		
Niacin		x		

Tables from: G.R. Beecher and J.T. Vanderslice, "Determinationof Nutrients in Foods: Factors That Must Be Considered," Modern *Methods of Food Analysis*, K. Stewart and J. Whitaker (eds.), 1984, pp. 34-41. Tables prepared from USDA, Nutrient Data Research Branch, Consumer Nutrition Division of the Human Nutrition Information Service research publications.

Variation in Nutrient Attributes

To ascertain whether the nutritional value of a fruit or vegetable varies among individual samples of the fruit or vegetable, relevant information for potatoes, tomatoes, apples, and oranges was collected by examining the past 10 years of International Food ScienceandTech*nology Abstracts.*

Nutritional variation was found to exist among samples of fruits and vegetables in several published studies. For example, protein, niacin, and thiamin increased in potatoes while ascorbic acid as well as starch decreased when nitrogen fertilizer was applied. Sandy soils increased the amounts of protein, ascorbic acid, riboflavin, niacin, sodium, and iron in potatoes but decreased the amounts of thiamine, magnesium, and calcium (2). One study (35) indicated that samples of a single potato cultvar may differ widely in sugar content after 9 weeks of storage. Incorporating phosphorus or potassium to the soil had no effect on protein or nonreducing sugars, but phosphorus increased the starch and sugar content of the potatoes.

Environmental factors influence the sugar-acid ratio, beta-carotene, and nitrogen content and quality of tomatoes (24). Nitrogen and potassium ratios also influence dry matter, soluble dry matter, and beta-carotene of fruits as well as their keeping quality. Maturity of the tomato affects total sugars and the ratio of reducing to nonreducing sugars as well as the percentage of total soluble solids. Mineral content and composition in tomatoes are influenced by location and growth but do not vary among cultivars. However, cultivar and fertilizer both affect the amount of ascorbic acid in tomatoes (25, 44).

In apples, seasonal variation affects anthocyanin, total phenol content, diameter and weight, total soluble acids, acidity, and Magnes-Taylor puncture values. Bruising and softening rates in cool storage varied by cultivar (13, 32).

Vitamin C in oranges was found to be influenced by variety, cultural practice, maturity, climate, fresh fruit handling, and processing factors such as packaging and storage. Percentage of juice, Brix, acidity, and total sugars varied with orange cultivar (40, 54).

In summary, the nutritive composition of fruits and vegetables varies due to factors of climate, geographical location, cultivar, soil variables, irrigation practices, fer-

Table 14-9—Knowledge of Nutrient Composition of Fresh Vegetables

Nutritional component	Little or no data	Substantial data	Inadequate data	Not applicable
Individual sugars			x	
Starch		x		
Nutrient fiber			x	
Total fat			x	
Fatty acids			x	
Cholesterol				X
Sterols			x	
Calcium			x	
Iron			x	
Phosphorous			x	
Sodium			x	
Magnesium			x	
Potassium			x	
Zinc		X		
Total protein		X		
Individual amino acids			x	
Folacin				X
Vitamin D			x	
Vitamin E			x	
Biotin	X			
Choline			x	
Pantothenic acid	X			
Vitamin A		x		
Vitamin B1 (Thiamin)		x		
Vitamin B2 (Riboflavin)		x		
Vitamin B6			x	
Vitamin B12				x
Vitamin C		x		
Niacin		x		

Tables from: G.R. Beecher and J.T. Vanderslice, "Determination of Nutrients in Foods: Factors That Must Be Considered," *Modern Methods of Food Analysis*, K. Stewart and J. Whitaker (eds.), 1984, pp. 34-41. Tables prepared from USDA, Nutrient Data Research Branch, Consumer Nutrition Division of the Human Nutrition information Service research publications.

tilization practices, and seasonal and annual variation. Post-harvest physiology and handling introduces additional sources of variation in the nutritional composition of fruits and vegetables.

Conclusion

Available evidence suggests that intracommodity variation in nutritional value does exist. Thus, one requirement for developing a grade standard based on nutritional characteristics is fulfilled. However, the lack of adequate data on several nutritive components of fruits and vegetables remains a problem. This deficiency needs to be rectified before nutritive attributes can be included in grade standards incomprehensive manner.

Assessing the Relationship Between Nutrient and Sensory Characteristics

Concept

Whether it makes sense to change from sensory-based grading to nutrient-based grading depends on the extent to which nutrition and sensory characteristics are related. To illustrate, consider the extreme case. Suppose all criteria contained within the sensory characteristics base for grade standards were positively correlated at 1.0 with whatever criteria were chosen for nutrition-related grade standard. This would imply little or no impact from a change to an alternative base. Obviously, however, it is more likely that some (but not all) sensory criteria are correlated with some (but not all) nutrition-related criteria.

As discussed earlier, current grade criteria for fruits and vegetables are based on three main considerations—quality, condition, and size. In general, the quality criteria involve maturity, cleanness, shape and form, color, and quality defects. The condition criteria generally involve firmness, condition defects, and color.

A matrix relating current sensory grade criteria to nutritional characteristics is presented in table 14-10. The current grade standards, generalized across all fruits and vegetables, appear as rows in the table. The columns are various nutrition-related characteristics. Some

Table 14-10-A Method for Conceptualizing the Relationship Between Sensory Characteristics and Nutrition Characteristics

Current grade criteria, generalized across all fruits and vegetables	Conceptual nutrition-related characteristics								
	Vitamins	Minerals	Calories	Enzymes & proteins	Carbo-hydrates	Fats & oils	Sodium	Calcium	Fiber
Quality									
Maturity									
Cleanness									
Shape/Form									
Color									
Quality defects									
Fungus injury									
Insect injury									
Mechanical injury									
Other[b]									
Condition									
Firmness									
Condition defects									
Decay									
Bruising									
Freezing									
Discoloration									
Ground color/color									
Size									

[a]The OSU study team believes that this list accurately portrays the criteria which predominate across all fruits and vegetables. However, there are some criteria in the current standards for a specific fruit or vegetable not reflected in this list. Such omissions have scant consequence for the present assessment.
[b]Other is defined as ill-shaped, undesirable color, sunburn, growth cracks, and/or dirt.

SOURCE: Office of Technology Assessment, 1992.

cells of the matrix are not expected to be of equal relevance. For example, one might expect positive correlation between maturity and calories per gram, whereas the fiber-insect injury cell might not have any correlation or importance. Similarly, if a nutrition-related base for standards were ever adopted, one would not expect all the criteria listed as columns in the table to be included in a standard. At this point, however, there are no compelling reasons to exclude cells formed by the matrix from examination, except for the cells involving cleanness and shape and form. These two current sensory grade criteria are not related to nutrition attributes. Therefore, these two rows are shaded to indicate no correlation is expected.

Each of the 126 relevant cells of the matrix, in effect, defines a specific topic where knowledge is desired. A task of the assessment of the nutrition-related base for grade standards was to carefully review existing scientific literature for each of the relevant cells for the four commodities chosen for analysis—potatoes, tomatoes, apples, and oranges. The past 10 years of volumes of the *International Food Science and Technology Abstracts* have been examined for research literature relevant to the matrix and the case study commodities.

Current Information

A summary of the findings is presented in table 14-11. A letter for each of the investigated commodities (A for apples, O for oranges, P for potatoes, and T for tomatoes) is placed in a cell if information existed about the nutrition-sensory relationship.

As is evident from the summary table, no scientific literature was found for many of the cells. For only about 8 percent of the 504 total cells (126 for each commodity) does at least one research article exists. No studies were found that investigated the relationships between current sensory grade characteristics and sodium while only one study examined calories. The inevitable conclusion is that much is unknown about the relationship between sensory characteristics and nutrition-related characteristics.

Nonetheless, some knowledge is available. The relationships between maturity and nutrition, especially with respect to vitamin C and carbohydrates, are the most researched. The concentration of vitamin C increases with maturity in potatoes and tomatoes, but decreases dramatically in oranges and potatoes the longer these commodities are held in storage. Carbohydrates in apples and tomatoes are positively related to ma-

Table 14-1 l—Summary Table of Scientific Literature on the Relationship Between Sensory Characteristics and Nutrition Characteristics for the Four Study Commodities.

Current grade criteria, generalized across all fruits and vegetables	Conceptual nutrition-related characteristics								
	Vitamins	Minerals	Calories	Enzymes & proteins	Carbo-hydrates	Fats & oils	Sodium	Calcium	Fiber
Quality									
Maturity	A, O, P, T	A,O, P, T	T	o	A, O, P, T	O, T		A,O,T	A, T
Cleanness									
Shape/form									
Color									
Quality defects									
Fungus injury									
Insect injury									
Mechanical injury . .					P				
Other[c]									
Condition									
Firmness ., ...									A, T
Condition defects									
Decay	0				o			A	
Bruising	P								
Freezing	P, T				P	T			
Discoloration									
Ground colorl/color . . .									
Size							P		

[a]**Key: A =** apples, O = oranges, P = potatoes, T = tomatoes
[b]% OSU study team believes that this list accurately portrays the criteria which predominate across all fruits and vegetables. However, there are some criteria in the current standards for a **specific** fruit or vegetable not **reflected** in this list. Such omissions have scant consequence for the present assessment.
[c]**Other** is defined as ill-shaped, undesirable **color, sunburn, growth** cracks, **and/or dirt.**

SOURCE: Office of Technology Assessment, 1992.

turity. In potatoes, starch is more readily converted to sugars after harvest. Conversely, oranges show a decrease in glucose and fructose during storage and as they decay.[3]

Chemicals and the Grading System

Current Pesticide Usage in the United States[4]

Herbicides, insecticides, and fungicides comprise the three major components of the $4 billion-a-year U.S. agricultural pesticide market. Herbicides surpassed insecticides in the late 1960s to become the most utilized pesticide class. With $2.5 billion in sales, they accounted for 90 percent of the total pesticide pounds applied in 1986. The insecticide agriculture market was second with $1.0 billion in sales, followed by fungicides with sales of about $265 million.

In 1982, slightly more than 500 million pounds of pesticide active ingredients were utilized in American agriculture. Pounds of pesticide active ingredients were 170 percent higher than in 19&l, while acres under cultivation remained essentially constant. By 1987, pounds of active ingredients had declined to about 430 million pounds. Ninety percent of all herbicides and pesticides are applied to four crops: corn, cotton, soybeans, and wheat.

Fungicides account for about 10 percent of all pesticides applied in agriculture and are the most significant pesticide product used in production of fruits and vegetables. Insecticide use is also significant in fruit and vegetable production, however, its use has declined in recent years through the adoption of new, more effective products and innovative strategies such as crop rotations and Integrated Pest Management.

Most new pesticide products introduced since 1980 have been herbicides. Thirty-seven herbicides have been registered with the Environmental Protection Agency (EPA) since 1980 as compared to 10 fungicides. This

[3]Note that many of these articles address post-harvest changes. These changes are not a maturity issue; however, they do illustrate the importance of post-harvest storage and handling techniques to the nutritional value consumers ultimately derive from a stored fruit or vegetable.

[4]Information i, this section comes from pages 43 through 49 of *Alternative Agriculture,* a report by the Committee on the Role of Alternative Farming Methods in Modem Production Agriculture, Board of Agriculture, National Research Council, 1989.

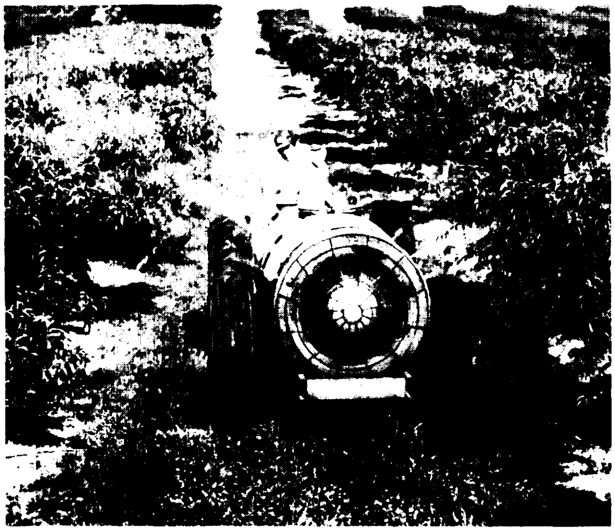


Photo credit: Grant Heilman, Inc.

Chemicals applied during production of fruits and vegetables may affect certain grade criteria. Enhanced grade quality is one of many reasons for using pesticides.

disparity reflects differences in the size of the market and the higher profitability of the herbicide class, which encourages new product innovation. Development of new fungicides is tricky due to a tendency for the development of pest resistance. Finally, fungicides have faced significant regulatory problems due to high carcinogenicity or oncogenicity. Although important to the production of fruits and vegetables, introduction of a new fungicide product can be a financial risk for the developing company.

Production of processing tomatoes in California and fresh market tomatoes in Florida and Ohio are discussed to highlight patterns of fruit and vegetable fungicide use. About 1.3 million tons of active ingredients are applied to the 304,000 acres devoted to these crops. California, which has 240,000 acres in processing tomatoes, uses 784 tons of fungicide active ingredient. On a pound-per-acre basis, however, the State uses only 6.5 lb per acre, compared to 11.5 lb per acre in Ohio and 17.9 lb per acre in Florida. The higher application rates in Ohio and Florida are due in part to the more rigid cosmetic requirements needed for fresh market production. More importantly, the more humid Midwestern and Southern climates necessitate increased levels of fungicide use.

The fungicide use pattern of tomatoes is representative of most fruits and vegetables. California uses less per acre because of its dry, favorable climate. But because it produces over half of the Nation's fruits and vegetables, California utilizes the largest share of fungicide products applied nationwide.

Pesticides and the Current Grading System

Chemicals applied during production may affect certain grade criteria in the current USDA grade standards for fruits and vegetables. An assessment of the relationship among various chemicals and current grade criteria was completed for apples, potatoes, and tomatoes. Tables 14-1 2–14- 14 summarize current, recommended cultural practices and the relationship of the chemical to current, selected USDA grade criteria. An ''X' is placed in each cell where the chemical's use affects the particular grade criterion. The summary reveals that chemical use primarily is relevant to three general grade criteria—fungus injury, insect injury, and decay. Thus, chemicals are used primarily to protect potatoes and tomatoes from fungal or insect damage.

While relationships between pesticide usage and grade criteria have been found, it is not clear whether or not current grade criteria encourage use of pesticides. Probably, improved grade quality is only one reason for using pesticides. Other reasons would likely include higher yield, better harvesting conditions, and reduced pest preserves on subsequent crops.

Chemical Residue Grading Standard

For an attribute to serve as a portion of a grade standard, variation in the attribute is necessary. Two recent surveys of chemical residues in food suggest that individual samples of fruit and vegetables are likely to exhibit differences in chemical residues. In 1989, the State of California sampled 9,403 food samples for pesticide residues (43). The following distribution was found:

Residue distribution	Percent of *samples*
No detectable residues	77.9
Residues 10% or less of tolerance level	13.0
Residues between 1O%. and 50% of tolerance level	7.4
Residues from 50% to 100% of tolerance level	1.0
Exceeded tolerance level	0.7

FDA annually tests about 20,000 samples of fresh and processed foods for residues exceeding tolerances established for 10,000 food additives and 300 pesticides (51). Foreign food imports make up a large proportion (36 percent) of the samples. In 1988, no residues were found in 60 percent of the samples tested. The remaining 40 percent contained detectable residues,

Table 14-12-Relationship Among Selected USDA Grade Criteria and Chemicals Approved for Use on Apples, Ohio, 1991

	Selected generic grade criteria				
Chemical (Scientific Name)	**Maturity**	**Fungus injury**	**Decay**	Insect injury	Size[a]
Growth regulator					
Fruitone N (1-Naphthalene-Acetic Acid)	x				
Herbicides					
Gramoxone (Paraquat) (Bipyridylnium)					x
Sinbar (3-tert-Butyl-5-chloro-6-methyluracil)					x
Karmex (Substituted Urea)					x
Fungicides					
Captan (Cis-N-trichloromethylthio-4-cyclohexene-2 1,2-dicarboximide)		x	x		
Benlate (Methyl-1 (butylcarbamoyl)-2-benzimidazolecarbamate)		x	x		
Dithane (Ethylene bisdithiocarbamate)		x	x		
Insecticides					
Oil (Oil solutions)			x	x	
Guthion (Organophosphorous-Pesticide family)			x	x	
Vendex (Organotin)			x	x	
Imidax (N-(Mercaptomethyl) phthalimide S-O, O-dimethylphosphorodithioate)			x	x	

[a]Very poor weed control can result in smaller size because of competition between weeds and the commercial crop.

SOURCES: Office of Technology Assessment, 1992, compiled from Ohio Crop *Enterprise Budgets, 1989: Specialty Crops,* The Ohio State University, Columbus, OH, p. 30 and *Farm Chemicals Handbook,* Meister Publishing Co., 1991.

but less than 1 percent of the samples exceeded EPA tolerances.[5]

EPA regulations exclude from the human food supply any commodity for which safe chemical residue levels are exceeded. This is not a grading question, but a food safety concern. However, assuming that the safe level for detectable residue is greater than zero, a grading standard hypothetically could be established on the basis of detectable levels of a specific chemical residue. The degree of detectable residue denotes a particular grade category. A hypothetical example appears in table 14-15.

Table 14-15 indicates that, if the level of detectable chemical residue were the only attribute used for grading, higher grades would be assigned to foods with successively lower residue levels.

Conceptually, each type of chemical would constitute a separate attribute. The set of chemicals deemed appropriate would then compose the standard. Another possibility would be to develop a summary index or weighted average measure for chemical residue. Such a summary index could allow the resultant grade to be assigned on the composite or summary score.

Conclusions

Implementation of a chemical residue attribute standard for fruits and vegetables would require decisions concerning which chemicals would form the standard. This task would be controversial and would require participation from a broad array of interested parties. It is reasonable to assume that some potentially usable chemicals would not be admitted to form the standards.

If a chemical residue grading system were implemented, lack of inclusion of naturally occurring toxic substances would be controversial. Naturally present phenolic compounds in fruits and vegetables have been found to be carcinogenic. Flavinoids tuercetin and campherol are present in many fruits and vegetables. Acetaldehyde, found in apples, is reported to be mutagenic. Aflatoxin is a fungal toxin and known carcinogen that can and does occur in virtually every fruit and vegetable from the fresh to processed state. Thus, a grading standard based on residues of chemicals ideally should include naturally occurring as

[5]Of the samples that exceeded tolerance levels, 84 percent involved cases for which there was no established EPA tolerance. Lack of an EPA tolerance level generally means that any residue deems the commodity to be "adulterated" and subject to regulatory action. Exceptions include "Unavoidable Pesticide Residues," which result unavoidably in certain processes under "good" agricultural and manufacturing procedures, and EPA "Emergency Exemptions," which are granted for use of nonregistered pesticides under certain emergency situations.

Table 14-13—Relationship Among Selected USDA Grade Criteria and Chemicals Approved for Use on Potatoes, Ohio, 1991

	Selected generic grade criteria				
Chemical (Scientific Name)	Maturity	Fungus injury	Decay	Insect injury	Size[a]
Vine Killer Dessicant					
Diquat (1,1 '-ethylene, 2,2' bipyridyliomion)[b]	x				
Herbicides					
Lorox (Linuron & Chlorimuron Ethyl)					x
Dual (Chloracetanilise)					x
Eptam (S-Ethyldipropylthiocarbamate)					x
Sencor-Lexone (Triazinone)					x
Fungicides					
Bravo (Chlorohalonil)		x	x		
Ridomil (Metzlaxyl & Mancozeb)		x	x		
/insecticides					
Di-Syston (Organophosphorous)			x	x	
Sevin (Carbamate)			x	x	
Phorate (Organophosphate)			x	x	
Guthion (Organophosphorous)			x	x	
Cygon(Carbamate)			x	x	

[a]Very poor weed control can result in smaller size because of competition between weeds and the commercial crop.
[b]Diquat is also applied to set potato skins.

SOURCE: Office of Technology Assessment, 1992, compiled from Ohio *Crop Enterprise Budgets, 1989:* Specialty Crops, The Ohio State University, Columbus, OH, p. 16 and *Farm Chemicals Handbook,* Meister Publishing Co., 1991.

Table 14-14-Relationship Among Selected USDA Grade Criteria and Chemicals Approved for Use on Staked Fresh Market Tomatoes, Ohio, 1991

	Selected generic grade criteria			
Chemical (Scientific Name)	Fungus injury	Insect injury	Decay	Size[a]
Herbicide				
Treflan (3,3,3-trifluoro-2,6-dinitro-N, N-propyl-p-toluidine)				x
Fungicides				
Bravo (Chlorothalonil)	x		x	
Benlate (Methyl-1 (butylcarbamoyl) -2-benzimi-dazolecarbamate)	x		x	
Insecticides				
Sevin (Carbamate)		x	x	
Thiodan (Chlorinated Bicyclic Sulfite)		x	x	

[a]Very poor weed control can result in smaller size because of competition between weeds and the commercial crop.

SOURCE: Office of Technology Assessment, 1992. Compiled from *Ohio Crop Enterprise Budgets, 1989: Specialty Crops*, The Ohio State University, Columbus, OH, pp. 3–5 and *Farm Chemicals Handbook,* Meister Publishing Co., 1991,

well as synthetic toxic substances. [6] Such a standard would be complex and controversial.

Options for an Improved Grading System

The purpose of the case study to this point has been to introduce the conceptual basis for two different fruit and vegetable grade standards—one based on nutritional content, the other on chemical residues. The investigation has determined three requirements for an attribute to serve, in whole or in part, as a grade standard. One requirement is that the attribute must vary across the produce to be graded. A second requirement is that information on the attribute must exist so that preferences can be assigned to gradations of an attribute. The third requirement is that the attribute must be measurable.

The assessment of conceptual alternatives has established that both nutrition and chemical residue attributes

[6] An argument can be made that humans have evolved over a long period of time eating these foods and have adapted to them and the chemicals in them. But humans have not evolved with pesticides so the impacts can be different.

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Table 14-15-Hypothetical Example of Grading System Based on Chemical Residues

Level of detectable chemical residue	Resultant grade
Greater than EPA established residue tolerance level	No grade, excluded from human food supply
<49% safety level	Grade C
50-90% safety level	Grade B
>90% safety level	Grade A

SOURCE: Office of Technology Assessment, 1992.

could be expected to vary across types of produce. Thus, the first requirement is met.

The second and third requirements are more complex and difficult to assess. The scientific literature review contained in this chapter reveals substantial gaps in the knowledge base required for either grading alternative.

Measurement, as a third requirement for an alternative grade standard, is a special issue. Current standards that primarily rely on sensory attributes mean that human graders can gauge the presence or absence of the attribute without mechanical assistance. Neither of the alternative standards is sensory in nature, implying the need for mechanical measurement. This, in turn, has significant implications for the viability and cost effectiveness of either alternative, given today's technology.

Mechanical measurement or testing likely would be slower and more costly than conventional grading by humans. Lower efficiency and consequent higher grading costs would probably occur for either the chemical residue or nutrition-based alternatives. This would raise consumer prices for fruits and vegetables.

The relative merit of implementing either alternative for fresh versus processed fruits and vegetables bears analysis. Consumers who purchase fresh produce at retail for at-home consumption presumably would benefit the most from information embedded in either alternative standard. Processing firms and firms in the food service industry (hotel, restaurant, and institutional away-from-home market) already can and often do test produce they purchase for nutrient or chemical residue characteristics. In addition, since nutritional labels are on most processed food products, a nutrition-based standard for processed grades would be redundant and of little value to the ultimate consumers.

OTA concludes that insufficient justification exists to recommend shifting away from the current sensory standards to either of the alternatives discussed here for the processed and food service markets. The argument for alternative grading for the retail at-home (fresh) market segment has more viability, and the ensuing discussion is limited to that portion of the market.

The chemical residue concept for a grading system combines the issue of food safety with that of food quality. The current food distribution system treats food safety and quality separately. That is, the current distribution and marketing system essentially assigns grades only to food determined safe for human consumption. The ''mixing' of these issues distinguishes the chemical residue attribute from the existing system.

The objective of implementing such a standard would be to provide consumer information on the amount of detectable residue below some "safe" level. Presumably this would allow consumer choice among various levels of ''safe for human consumption residue' at alternative prices. However, the chances for consumer misinformation from such an attribute probably would be quite high. Consumers could easily misconstrue the information to mean that some foods on the market are not safe. Because of these problems, the chemical residue base for standards is dismissed as a viable alternative by OTA, even for the retail at-home fresh fruit and vegetable market segment.

Thus, three viable policy options arise from this analysis: abolishing current retail grades and standards, relying on point-of-sale (POS) nutritional labeling, and modifying the current Federal standards to reflect some information on nutrient content. An evaluation of each policy option follows.

Option l—Abolishing Grades

Consumer grade standards exist, but seldom are used. Explanations that might account for the limited use of consumer grade standards include the following:

- retail grades are not useful as a merchandising device, and
- retail grades do not convey any additional information beyond that embodied in wholesale grades.

Regardless of the reasons for lack of use of retail grades, it is clear that abolishing them would not have a direct and significant impact on the marketing of fruits and vegetables.

Because grade standards are used extensively for wholesale trading, abolishing wholesale grades would have significant economic consequences for the fruit and vegetable industry. Some immediate and obvious consequences would result:

- transactions costs associated with trades would increase.
- marketing efficiency would decline.
- marketing information would become less meaningful because price differentials by quality would be less accurate, and
- fewer buyers would be available for a given seller (i.e., geographical area of trades would diminish).

Without the impartial information conveyed through grade standards, fruit and vegetable marketing would experience a significant decline in overall efficiency. Commodities previously bought by grade descriptions would require inspection by buyers, producing a decline in the efficiency with which fruits and vegetables are shipped from production areas to consuming areas. Such inspection also would reduce the area over which commodities could be traded, thereby limiting market competition and raising commodity prices at the wholesale and retail level. Moreover, while the current grading system facilitates grading at the shipping point level, abolishing grades would encourage trade consummation at terminal markets. Previous experience has already shown that terminal market transactions are less efficient than the current geographically dispersed system (i. e., most produce bypasses terminal markets because chain stores buy direct from shipping point markets).

Although grade standards primarily are used to facilitate wholesale trading, abolishing them is likely to have significant impact at the consumer level. For example, one reason grades might not be used at the consumer level is that their use at the wholesale level captures the relevant attributes for consumers. That is, attributes such as color, maturity, shape, and size, which facilitate wholesale transactions, are likely to be important for consumer transactions. If these attributes are not used for wholesale transactions, then consumer purchases at the retail level that are based on these attributes are likely to be impeded.

Option 2—Point of Sale Nutritional Labeling

The U.S. Congress in 1990 passed and the President signed a fruits and vegetables nutritional labeling law. The law stipulates that the content, format, and delivery of fruit and vegetable nutritional labeling is to be determined by the Food and Drug Administration (FDA). In general terms, the bill will require the posting of point of sale (POS) signs that detail the nutritional content of the 20 most frequently consumed fruits and vegetables. During an 18-month period following signing of the law, compliance is voluntary. Should compliance be deemed insufficient, a provision in the law enables the FDA to then make in-store nutritional labeling mandatory.

The bill had the general support of industry trade associations such as the United Fresh Fruit and Vegetable Association, the Produce Marketing Association, and the Food Marketing Institute. The final compromise legislation proved to be less onerous than earlier versions of the bill, which would have called for labeling of virtually all produce sold in stores. The trade associations view labeling as positive because of the opportunity to present information highlighting the nutritional benefits of produce. The conclusion drawn by the produce industry, in terms of labeling's potential impact on sales, is that to the extent that consumers are better informed about the nutritional quality and healthful benefits of fruits and vegetables, overall sales of fruits and vegetables should go up. These indusry groups, however, do not support the idea of mandatory labeling and therefore are working to assure high voluntary compliance. Additionally, they seem to be advocating simplified labeling with information on calories, carbohydrates, fiber, vitamin A, and vitamin C.

The production of nutritional labels (signs) that presumably would be posted in every retail food store in the country under this legislation will entail significant startup costs. Once the labeling system has been put into place, maintenance costs should be modest. The nutritional components of the produce to be displayed in the labeling will come from government published data, and the signs (or labels) themselves will become permanent fixtures within produce departments. Open to question is the extent to which implementation costs may be passed on to consumers. Little direct cost will be incurred by produce retailers. The labeling will be provided by various industry trade associations, and the signs and labels should be freely available in the 18-month "voluntary" initial phase of the law as the various industry groups are interested in bolstering participation to stave off mandatory labeling.

The final form nutritional labeling will take is still being worked out between the FDA and interested industry and consumer advocacy participants. The produce industry perceived several years ago that nutritional labeling was an inevitability. By becoming involved with nutritional labeling in its early stages, the industry can exert influence on the form nutritional labeling would take.

A survey by Opinion Research Corp. commissioned by the National Food Processors Association in late 1989 found that 4 of 10 consumers say that the first time they buy a food product they read the labels for general nutritional information and make purchasing decisions based on their comparisons. The survey results report that the more nutritionally sound a food product is (e. g., breakfast food v. snack food), the more likely consumers are to buy it. Other research has revealed that perceived negative food attributes such as high sodium or cholesterol contents are just as important as positive attributes in formulating consumer decisions to buy one food product over another. Significantly, the proposed produce labeling is limited to nutritional attributes perceived by consumers to be positive.

The final form that nutritional labeling will take may favor some fruits and vegetables over others in marketplace competition. First, determining which are the top 20 fruits and the top 20 vegetables by consumption is difficult: there seems to be some jockeying for a place among positions 15 through 20. In these lower ranking categories, consumption statistics do not indicate clear winners. Foods that do carry nutritional labels probably will attract consumers and lead to sales increases at the expense of the lower rated foods. A second important implication of nutritional labeling in terms of marketplace competition relates to display of the nutritional information. Will labeling take the form of presentation of aggregate data at a centralized location, with the 40 produce products ranked on attributes; or will each produce bin have a unique sign with nutritional attributes displayed solely for that product? Research indicates that, for aggregate data, sequencing would have an impact on consumer purchase decisions. If, for example, ranking occurred on a positive (negative) nutritional attribute, then consumers would be steered toward (away from) purchase of the higher ranked food.

The nutritional labeling law will present the FDA with another program area to administer. Therefore, some governmental costs will be incurred. After FDA's initial involvement of writing provisions of the legislation, however, its involvement will be limited to measuring compliance. Should the labeling legislation become mandatory, then it is possible that administrative costs related to enforcement could rise.

Option 3—Modifying Grades

Basing Federal fruit and vegetable grades for the at-home retail market in part on nutrient characteristics presents an interesting and plausible option. The scientific knowledge base for this option is relatively adequate though not comprehensive in scope. The possibility of combining some nutrient attributes with existing sensory characteristics appears feasible. For example, the relationship between maturity in the current standards and several nutrient attributes is fairly well established.

The economic impact and cost of adjustment to some nutrition-based grade standards, especially if they were mandatory, would be substantial. Transactions costs would increase for some period of time during adjustment to the new standards. Costs of grading would increase, especially if destructive testing for nutritive content were necessary. Consequently, during the adjustment period, prices for fresh fruits and vegetables at retail likely would be higher and producer prices lower.

After some period of adjustment, nutrition-based grading standards would become customary for all firms involved in the marketing channel-producers, wholesalers, and retailers. At this point, transaction costs of using the new system should not be significantly different from the previous sensory standards; however, grading costs would be higher because nutrition-analysis requires the use of instruments and experts. These increased transactions costs would be passed on to consumers in the long run.

The distribution of costs to various industry participants would be different during the adjustment period than in the long term. Initial uncertainty about the new standards would increase transaction costs to users of the new standards. If use of the new standards were voluntary, relatively higher transaction costs would discourage use of the new system by wholesalers and retailers. Instead, they would use the former standards or rely on trade associations or comparable groups to define standards similar to the old system. Furthermore, over the longer term, the higher transaction costs would result in higher costs to consumers and/or lower prices for producers.

The shift to a grading system based in part on nutrition criteria would probably diminish the historic role the Agricultural Marketing Service has played in grading and enhance the role of FDA. The food science component of FDA would be a more natural focal point for regulatory and compliance activities.

Conclusions

A summary table of the conclusions concerning the potential viability of the alternative conceptual bases ex-

Table 14-16—Summary Conclusions on Potential Viability of Conceptual Grading Alternatives

Market segment	Chemical base	Nutrient base
Fresh At-Home	Costly to implement Sparse scientific knowledge base May impart misleading information	Costly to implement Inadequate current scientific knowledge base Advantage lessened by recent nutritional **information point-of-sale program** **Relatively most viable**
Away-from-Home	Marginal value to consumers Costly to implement	Marginal value to consumers Costly to implement
Processed	Marginal value to consumers Costly to implement	Marginal value to consumers Costly to implement

SOURCE: Office of Technology Assessment, 1992

amined is presented in table 14-16. Before either the nutrient or chemical base could be implemented on a cost-effective basis, advances in measurement technology would need to occur. This is on the horizon, but until advances occur, the wisdom of adopting an alternative base seems marginal from a societal perspective. At the current time, neither the scientific information base or the technology for measurement permits nutrient attributes to be an exclusive grade standard for fruits and vegetables.

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