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QUALITY OF AGRICULTURAL PRODUCTS IN RELATION TO PHYSICAL CONDITIONS

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Definition

Quality. Degree to which a set of inherent characteristics fulfills requirements (ISO 9000:2005).

Agricultural Products. In broad terms, food and fiber products. For more detail, see the Introduction section below.

Physical condition of agricultural products. In broad terms, everything related to the properties that can be observed or measured without changing the composition of the product matter. More specifically, the physical condition of, e.g., a fruit is related to textural aspects. Physical conditions determining agricultural products quality depend on the product considered.

Introduction

The quality of a commodity depends greatly on the intended use. As this entry deals with quality of agricultural products (see *Agrophysical Objects (Soils, Plants, Agricultural Products, and Foods)*), it seems reasonable to start by identifying what commodities are included in the term *agricultural product*, and what their possible uses are. The United States Department of Agriculture (USDA) points out that agricultural products, sometimes also referred to as "food and fiber" products, cover a broad range of goods; specifically, all of the products found in Chapters 1–24 of the U.S. Harmonized Tariff Schedule – except for fishery products, manufactured tobacco products like cigarettes and cigars, and spirits – are considered agricultural products. Agricultural products within these chapters generally fall into the following categories: grains, animal feeds, and grain products (like bread and pasta); oilseeds and oilseed products; livestock, poultry, and dairy products including live animals, meats, eggs, and feathers; horticultural products including all fresh and processed fruits, vegetables, tree nuts, as well as nursery products and wine; unmanufactured tobacco; and tropical products like sugar, cocoa, and coffee. Certain other products outside of Chapters 1–24, like raw rubber, raw animal hides and skins, and wool and cotton, are also considered agricultural products. To illustrate the wide variety of uses of agricultural products, let us take the corn grain as an example. While its main use is for livestock feed, corn grain is also used for human nourishment under the forms of corn cob, sweet tender canned corn, corn flakes, margarine elaborated from corn oil, etc., and through the industrial process of corn wet milling, to obtain starch and starch-derived chemicals. This cornstarch is then processed and used as food (e.g., as thickener in the food industry) and industrial products. It is routinely used as an adhesive, for manufacture of papers, and as an excipient or filler for pharmaceuticals. It can be converted into an enormous assortment of industrial chemicals now produced from petroleum sources. For example, new biodegradable plastic products are being made from corn, such as garbage bags, car parts, and packing "peanuts" (Olson and Warren, 2010).

Given the heterogeneity of agricultural products and their possible uses, to dissert on their quality it is convenient to focus on some agricultural products and specific uses. This article focuses on products obtained from cultivated plants for purposes of human nourishment, both in raw and processed form. More specifically, here we deal with grain and horticultural produce destined for human consumption. Other agricultural products as foods

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obtained from animals (fish, meat, milk, eggs, etc.), or fibers of vegetal and animal origin (cotton, flax, wool, silk, etc.), are beyond the scope of this entry. Grains, and especially fruits and vegetables, are living, respiring, biologically active organisms that require optimal storage conditions (see *Physical Phenomena and Properties Important for Storage of Agricultural Products*) to maintain the quality that is present at harvest. A major difference between horticultural produce and grains is that horticultural products, mainly due to much higher water content, have to be stored under refrigeration, whereas grains do not.

According to Sloof et al., (1996), quality is a very elusive concept, which depends on several factors, the major of which are the product itself and its intended use. For instance, the required degree of ripeness of an olive depends on whether it will be seasoned for consumption as *table olive* or it will be processed for extracting olive oil. While most types of table olives are harvested before véraison, i.e., when they are green or immature, olives intended for oil extraction must be mature enough (véraison or purple turning to black). In both cases, the destination of olives is the food industry since these fruits, due to a glucoside in the flesh called *oleuropein*, are too bitter to be eaten raw. Olive is not the only horticultural produce that cannot be eaten raw; e.g., potatoes are never eaten row, and quince flesh is so hard that all its production is processed. Another example of quality dependence on the intended use is in the fresh oranges we purchase for home consumption. Typically, there are two ways of using these oranges: one is eating the whole fruit – except the peel – and the other is making them juice. When a consumer buys *juice oranges*, he will normally expect a maximum content of juice, and the lesser fiber possible. But if he wants *table oranges*, i.e., oranges for being eaten whole, his preferences might differ. A third example can be mentioned for tomato. For fresh consumption, as in salads, a thick skin is a negative attribute, but if the tomato is to be processed, it should have a thick skin, in order to remain intact until it reaches the factory. The latter requirement arises because processing tomatoes are harvested mechanically, and this operation entails potential damage (see *Mechanical Impacts at Harvest and After Harvest Technologies*). If machine-harvested tomatoes had a thin skin, they would break easily, and the losses of juice would be considerable. In practice, processing tomato varieties are different from fresh-market varieties. Within fresh-market tomatoes, the quality desired by the consumer will vary depending on the intended use: ripe tomatoes for soup, hard tomatoes for salads. A last example can be addressed for peaches. Peach varieties can be classified as *freestone* or *clingstone*. Freestone peaches are destined for fresh consumption, whereas the peach canning industry demands exclusively clingstone peaches, since they have a harder flesh than their freestone counterparts. Apart from the product itself and the intended use, there are sociopsychological factors that play a role in defining the quality, since they affect the user's attitude toward the product. For example, one person may be status conscious and prefer bananas from Spain's Canary Islands or plum tomatoes from Italy, another may be environmentally aware and prefer organically grown tomatoes. On the other hand, physical conditions determining the quality of grain and horticultural produce depend on the product under consideration.

Grain

Physiological maturity and maximum dry matter yield of winter cereals (wheat, barley, rye, oats) is reached when the grain moisture content is between 30% and 40%, but at this moisture content the grain is too soft to combine (see *Physical Properties of Raw Materials and Agricultural Products*). Grain is usually combine ready (sometimes referred to as "harvest ripe" or "grain ripe") when it has dried to about 15% moisture (Farrer et al., 2006). Besides, this is the moisture content limit required for safe storage. Harvest delay is not recommended, as it usually results in yield reduction due to hail damage, insects or birds attack, lodging, or shattering. Shattering occurs when the spikelets or grains fall from the plant. Moreover, when harvest is delayed the combine operation may be hindered by weeds infestation; weeds may even fructify, producing seeds that will be harvested together with the grain, contaminating it. In the case of rice, the drawbacks associated to harvest delay are the same as for winter cereals, plus the fact that rice will fissure while on the panicle if allowed to dry below certain levels and subsequently incur rapid moisture adsorption. Rain or exposure to high relative humidity could cause such adsorption. Therefore, in most countries, rice is not allowed to dry too much in the field after physiological maturity, but it is harvested with high moisture content (25–30%). Afterward, rice is dried down to safe storage conditions, about 15% moisture content, at dedicated facilities (see *Drying of Agricultural Products*).

The main cereals used for human nourishment internationally are wheat and rice. However, for the poorest rural people in the semiarid tropics of Asia and Africa, sorghum and millets are the most important staple foods, growing in harsh environments where other crops do not grow well (FAO, 1995). Barley is also important internationally insofar it constitutes the raw material for beer making (brewing). Rye is traditionally used for bread making in some European countries, competing with common bread made from wheat. Rye bread has the advantage over wheat bread of remaining tender during several days, while wheat bread soon dries and hardens (see *Water Effects on Physical Properties of Raw Materials and Foods*). Finally, white corn is of utmost importance in Spanish-America countries, such as Mexico or Peru, where it is used to produce *tortillas* and other traditional staple foods.

Wheat

Worldwide, the main use of wheat grain is for bread making. Species used in bread making is the *common wheat* or *bread wheat* (*Triticum aestivum* L.), whereas *durum wheat* (*Triticum turgidum* ssp. Durum) is used to make pastas. Bread wheat mills to produce flour, whereas durum wheat mills to produce semolina, which has a coarser granulometry than flour. Depending on the variety, bread wheat can be soft or hard. Moreover, grain can be *white* or *red*. Attending to the duration of the vegetative cycle, there are winter wheat (long cycle) and spring wheat (short cycle) cultivars. Within bread wheat, soft wheat varieties are generally used to make biscuits and other bakery products, whereas hard cultivars are used to make loaf bread.

Wheat milling factories transform the grain into flour, which is then sold to bread-making facilities. According to the United Kingdom Home-Grown Cereals Authority (HGCA), the quality parameters analyzed by wheat millers for each grain delivery are: moisture content, specific weight (*test weight*), screenings and admixture, wheat variety, protein content, protein quality, Hagberg Falling Number, molds, damaged grain and odors, and grain hardness. Grain moisture content does not directly affect grain quality, but can indirectly affect quality since grain will spoil at moisture contents above that recommended for storage (15%); this is because insects and molds, the causing agents of spoiling, require moisture to grow.

Thin, shriveled grain will not mill to produce adequate amounts of clean, white flour. Grain *test weight* is used as an indicator of general grain quality and is a measure of grain bulk density. The *test weight* measures the weight of wheat (in kg) that can be packed into a cylinder of fixed volume, normally 1 L. Wheat standards fix a minimum specific weight (Table 1). *Test weight* is composed of two components: the packing efficiency of the grain and the density of the individual kernels. Packing efficiency is dependent on genotype, while kernel density is primarily affected by environment (Farrer et al., 2006). Schuler et al. (1995) found that *test weight* did not predict flour yield in soft red winter wheat when shriveling was absent,

Quality of Agricultural Products in Relation to Physical Conditions, Table 1 Grades and grade requirements for all classes of wheat except Mixed wheat. Source: United States Standards for Wheat. Grain Inspection, Packers and Stockyards Administration. United States Department of Agriculture (2006)

	Grades U.S. Nos.				
Grading factors	1	2	3	4	5
Minimum pound limits of:					
Test weight per bushel					
Hard Red Spring wheat or White Club wheat	58.0	57.0	55.0	53.0	50.0
All other classes and subclasses	60.0	58.0	56.0	54.0	51.0
Maximum percent limits of:					
Defects:					
Damaged kernels					
Heat (part of total)	0.2	0.2	0.5	1.0	3.0
Total	2.0	4.0	7.0	10.0	15.0
Foreign material	0.4	0.7	1.3	3.0	5.0
Shrunken and broken kernels	3.0	5.0	8.0	12.0	20.0
Total[a]	3.0	5.0	8.0	12.0	20.0
Wheat of other classes:[b]					
Contrasting classes	1.0	2.0	3.0	10.0	10.0
Total[c]	3.0	5.0	10.0	10.0	10.0
Stones	0.1	0.1	0.1	0.1	0.1
Maximum count limits of:					
Other material in 1 kg:					
Animal filth	1	1	1	1	1
Castor beans	1	1	1	1	1
Crotalaria seeds	2	2	2	2	2
Glass	0	0	0	0	0
Stones	3	3	3	3	3
Unknown foreign substances	3	3	3	3	3
Total[d]	4	4	4	4	4
Insect-damaged kernels in 100 g	31	31	31	31	31
U.S. Sample grade is Wheat that:					
(a) Does not meet the requirements for U.S. Nos. 1, 2, 3, 4, or 5; or					
(b) Has a musty, sour, or commercially objectionable foreign odor (except smut or garlic odor) or					
(c) Is heating or of distinctly low quality.					

[a]Includes damaged kernels (total), foreign material, shrunken and broken kernels
[b]Unclassed wheat of any grade may contain not more than 10.0% of wheat of other classes
[c]Includes contrasting classes
[d]Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, or unknown foreign substance

but it was related to flour protein content, which is associated with bread-baking quality. Grain *test weight* normally increases as grain is dried (Table 2).

Screenings are undersized grains, and admixture comprises impurities, e.g., chaff, weed seeds and earth, which must be removed before milling marketable flour. Screenings and admixture represent a loss to the miller, so a maximum of 2% is normally allowed (HGCA). A synonym of admixture is *foreign matter*, and these terms should not be confused with the term *dockage*. The latter refers to any non-wheat material that can be easily removed from grain, and that must be removed in order that the grain can be assigned the highest grade for which it qualifies.

Protein content is specified for all bakery flours. For most bread-making flour, wheat with protein content above 13% dry matter is preferred (HGCA). When wetted, during dough making, some of the proteins in wheat flour form a viscoelastic (see *Rheology in Agricultural Products and Foods*) substance called gluten. This can hold gas produced during fermentation and supports the starch and bran producing well-risen loafs. For most biscuits and cakes, gluten formation is not required; hence, much lower protein flours may be used.

Visual examination assesses grain for molds, like *Fusarium* (pink grains) and particularly ergot. Ergot is a disease of cereal crops and grasses caused by the fungus *Claviceps purpurea*. It causes reduced yield and quality of grain. Although the crop loss caused by this disease is important, the effect of the ergot's alkaloid toxins on man and animals is of much greater significance. Most of the sclerotia (ergot bodies) can be removed from ergoty grain with modern cleaning machinery, unless broken pieces are present or the sclerotia are similar in size to the grain (Mc Mullen and Stoltenow, 2002). Ergot is a particular problem in durum wheat because semolina is not sifted, as flour is for bread, and ergot shows up as dark spots in the pasta. Apart from visual examination for molds, checks are made for live insects and grain damaged by insects. Grain is also assessed for unusual odors; "mustiness" or "chemical" odors indicate storage problems.

Quality of Agricultural Products in Relation to Physical Conditions, Table 2 Test weight variation due to moisture content (Hellevang, [1995])

Grain	Moisture content (%)	Test weight (kg/hL)[a]
Wheat	11.5	79.2
	13.5	77.4
	15.5	75.6
Corn	13.5	73.9
	15.5	72.2
	17.5	70.5

[a]Original values in lb/bu. Conversion factors applied: 1 lb = 0.454 kg; 1 U.S. bu = 35.24 L

The Hagberg Falling Number (HFN) is an internationally recognized measure that allows the indirect determination of α-amylase activity (α-amylases are enzymes that decompose starch). This activity may become excessive if germinated grains are present. The laboratory measurement of HFN aims to measure the viscosity of a mixture of ground wheat and water, placed in a bain-marie at 100°C. Low values for HFN (below 120 s) mean excessive levels of α-amylase, hence excessive activity, causing loaves to be discolored, sticky, and of poor resilience and texture (see *Rheology in Agricultural Products and Foods*). The ideal level of activity is between 180 s and 250 s (GeotraceAgri project, 2003). Wheat grains whose α-amylase activity is too high do not suit bakery use and rather should be used for animal feeding.

In regards to durum wheat, Jiménez González (1995) pointed out the following quality criteria:

– Grain moisture content must be the lowest possible.
– Small grains are not valid for milling, due to the low endosperm/seed coat ratio.
– Grain size must be uniform.
– Germinated grains can yield pasta of bad cooking quality.

Rice

Rice, unlike most other cereals, is consumed as a whole grain. Therefore physical properties such as size, shape, uniformity, and general appearance are of utmost importance. A whole grain of rice, i.e., a grain of rice as it comes from the field after harvest (*paddy rice* or *rough rice*) has several constituent layers. More precisely defined, paddy rice is rice which has retained its husk after threshing (Codex Standard for Rice, 1995). Only the outermost layer, the hull or husk, is removed to produce *husked rice*, more commonly known as *brown rice* or *cargo rice*. This process is the least damaging to the nutritional value of the rice and avoids the loss of nutrients that accompanies further processing. If brown rice is further milled to remove the bran and most of the germ, the result is a white rice, but also a rice that has lost many more nutrients. At this point, however, the rice is still unpolished, and it takes polishing to produce the white rice we are used to seeing. Polishing removes the aleurone layer of the grain, a layer filled with essential fats, to extend the shelf life of the product; polishing is important because fats in the aleurone layer, once exposed to air as a consequence of the previous stage in the refining process, are highly susceptible to oxidation. The drawback of the refining–polishing process is that the resulting white rice is largely bereft of its original nutrients (The George Mateljan Foundation, 2010). To compensate the loss of nutrients, vitamins, minerals and specific amino acids may be added in conformity with the legislation of the country in which the rice is sold (Codex Standard for Rice, 1995).

Because most rice is milled, the important physical properties are determined primarily by the milled endosperm. Several components of rice quality largely determine market price and consumer acceptance. Milling yield is one of the most important criteria of rice quality. Two values of rice milling yield are *whole-grain yield* and *total* (whole plus broken) *milling yield*. Broken rice is generally valued at only 30–50% of whole grain (Mutters, 2003). Physical characteristics of rice considered important by the quality standards for rice in force in Japan include:

– The number of whole grains (damaged, opaque, immature, foreign matter)
– The number of damaged grains (germinated, diseased, insect-damaged, cracked grains, malformed)
– Morphology parameters (periderm thickness, filling status, softness, uniformity of grain size, shape, luster, abrasion, white core, white belly)

The second major criterion of quality in Japanese standards for rice is taste. Good eating quality relates to high stickiness, sweet flavor, gloss of cooked rice, and palatability.

Barley

There are two main types of barley: six-row and two-row. Generally, two-row barley has lower enzyme content, less protein, more starch, and a thinner husk than six-row barley (Goldammer, 2008). These characteristics make two-row barley the preferred one for brewing in most countries. However, six-row barley outperforms its two-row counterpart as to enzymes content. In those breweries or elaborations where *adjuncts* – corn and rice – are used in the elaboration process, six-row barley is preferred, since in this case a highest amount of enzymes is required. Brewing exclusively from barley produces strong-flavored beers, whereas blending with some percentage of rice or corn makes beer "lighter," but more refreshing.

The brewing process begins at the malthouse. In these facilities, after cleaning the grain, the kernels are steeped to make them germinate. At a certain moment, germination is stopped by drying the grains (*kilning*), then the tiny sprouts developed at germination are removed. The produce obtained, *malted barley*, is the raw material for the breweries and differs from raw barley in that the original starch in the barley grain has suffered some amount of degradation by enzymes; in technical language it is said that the starch has been *modified*.

Correct harvesting of barley is critical to maximize both yield and quality. Grain that is overthreshed causing cracking and *skinning* will have poor viability and result in low malt extract as well as increased risk of microbial infection when malted. Maltsters and brewers require grain that is free from skinning. The presence of a complete husk on barley protects the embryo during handling (the embryo must be protected because it is the agent in charge of converting the barley into malt), retains the modified starch within a parcel, and is used as a filtration aid during brewing (Department of Agriculture and Food, Government of Western Australia, 2006).

The maltster wants little nitrogen in the barley because excessive proteins in the grain prolong the process of malting, making it more difficult and more expensive. Not only that, but excessive of protein in beer reduces both the quality and shelf life of the beer (Holder, 2002). For example, chill haze in beer is partly caused by excessive protein content. The brewer has to adopt a trade-off between reducing protein content to improve colloidal stability, i.e., preventing haze development, and affecting fermentation and beer quality (if the protein content is too low, the yeasts in charge of the alcoholic fermentation will not work well, and on the other hand, the "mouthfeel" of the beer will negatively be affected). Barley growers know that fertilizing the crop too much nitrogen can increase protein beyond levels acceptable to the malting industry's standards.

The maltster wants barley varieties characterized by rapid and synchronous germination of the grains. An important quality test undertaken by maltsters upon reception of a lot of barley is the germinative capacity test. A highest germination capacity is crucial since only germinated grain will produce malted grain. The ideal germination capacity is of 100%. In practice, a minimum germination capacity of 95% is required for a grain delivery to be accepted.

Grain size is a term used to describe a morphological character (see *Grains, Aerodynamic and Geometric Features*) of barley grain. Large grain will usually provide a higher level of starch with a decreased level of protein (Fox et al., 2006). On the other hand, although barley varieties with small grains can provide satisfactory malting quality, these varieties risk producing commercially unacceptable levels of small grain and thereby reduce the chance for barley growers to meet malt barley specifications (Fox et al., 2006). Finally, varieties exhibiting varying grain size within a delivery can cause uneven malt *modification*.

Fruits and vegetables

Fruits and vegetables are irreplaceable in a wholesome diet. They constitute a fabulous source of vitamins, minerals, and dietary fiber (non-starch polysaccharides). The assortment of horticultural produce is enormous. There are green leafy vegetables as lettuce, spinach, and kale; bulb vegetables as onion, garlic and leek, root vegetables as carrot and turnip, flower vegetables as cauliflower and broccoli; stem vegetables as celery and asparagus; fruit vegetables as pepper, melon, watermelon, zucchini (courgette, marrow), cucumber, pumpkin, and aubergine (eggplant); tropical fruits as mango and papaya; sweet fruits of temperate areas like plums and apricots; berries, etc. There are also tree nuts and mushrooms – strictly speaking the latter are not plants – they belong to the Kingdom Fungi. In the last decade, some sweet fruits of temperate areas like kiwifruit or persimmon have experimented notable production increase. From a worldwide economic point of view, some of the more relevant fruits and vegetables are apples, peaches, citrus fruits (orange, tangerine, lemon, grapefruit), potato, and tomato, and in following sections we focus on them.

Fruits and vegetables marketing standards establish the main quality criteria that fresh-market products have to meet. The European Communities (EC) Commission Regulation 1221/2008 provides a *general marketing standard* for 26 products, namely, apricots, artichokes, asparagus, aubergines, avocadoes, beans, Brussels sprouts, carrots, cauliflowers, cherries, zucchini, cucumbers, cultivated mushrooms, garlic, hazelnuts in shell, headed cabbage, leeks, melons, onions, peas, plums, ribbed celery, spinach, walnuts in shell, watermelons, and chicory. The foregoing Regulation also provides specific marketing standards for the ten most traded products in the European Union, namely, citruses, apples, pears, kiwifruits, lettuces, peaches and nectarines, tomatoes, strawberries, sweet peppers, and table grapes.

Now let us take one of the specific quality standards, e.g., that for kiwifruit, for examining some aspect of it. The marketing standard for kiwifruits (EC Commission Regulation 1221/2008) includes *minimum maturity requirements* consisting of that the fruit must have attained a degree of ripeness:

- At packing stage within the region of production and the subsequent delivery by the packer, as well as at import and export stage, of at least 6.2°Brix or an average dry matter content of 15%
- At all other marketing stages (e.g., at the sale point), of at least 9.5°Brix

The unit °*Brix* is a measure of sugar or soluble-solids content very much used for internal quality assessment of fruits. In the last few years, some packers have installed near-infrared spectrophotometers for online determination of fruit sugar content in their packinghouses (see *Nondestructive Measurements in Fruits*). This new capability is advertised by packers as *brix sensoring*.

Apart from the minimum maturity requirements above-mentioned, the marketing standard for kiwifruits provides shape requirements for the fruits to be classified as *Extra class* or *Class I*. For qualifying *Extra class*, the ratio of the minimum/maximum diameter of the fruit, measured at the equatorial section, must be 0.8 or greater, while for qualifying *Class I*, the ratio must be 0.7 or greater. This means that a kiwifruit of *Extra class* has to present a rather round cross section. Three dimensionally considered kiwifruits feature a maximum length axis, called polar axis, plus an intermediate and a minimum length axis, the two latter contained in the fruit cross section. In the ideal case of a fruit featuring a perfect circular section, the major and minor axis of the equatorial section would coincide. If a kiwifruit has a ratio smaller than 0.7, it means that its cross section is rather elliptical or flattened, i.e., the fruit has an "ugly" shape. Finally, the marketing standard for kiwifruits includes provisions concerning the sizing of the fruits. Sizing means sorting by size, and the size of kiwifruits is determined by the fruit weight. Likewise, for some other produce, e.g., lettuce, the size is determined by the weight of one unit; nevertheless, for other products such as citrus fruits, size is determined by the maximum diameter of the equatorial section.

The *minimum quality requirements* of the EC *general marketing standard* establish that the products shall be:

- Intact
- Sound; products affected by rotting or deterioration such as to make them unfit for consumption are excluded
- Clean, practically free of any visible foreign matter
- Practically free from pests
- Practically free from damage caused by pests affecting the flesh
- Free of abnormal external moisture
- Free of any foreign smell and/or taste

In each batch the standard allows a tolerance of 10% by number or weight of product not satisfying the foregoing *minimum quality requirements*. This tolerance does not, however, cover product affected by rotting or any other deterioration rendering it unfit for consumption. Unlike the specific marketing standards for the above-mentioned group of ten products, the EC *general marketing standard* does not include provisions concerning sizing or shape. It seems that this decision pursues that *off-size* and *off-shape* fruits can be dispatched to fresh market instead of being classified as culls and destined for processing or animal feeding. The advantage of diverting these "ugly" fruits to the fresh market is that their price should accordingly be lower, and this is good in the present world economic conjuncture of crisis.

Apparently trivial physical properties may have a definite effect on the quality of the end product. For example, from the wine-making point of view, grape berry has three major types of tissue: flesh, skin, and seed, with the sheer bulk of wine being derived from the flesh. These tissues vary considerably in composition, and therefore by extension, they contribute differently to overall wine composition. Because of this, the composition of wine can be manipulated by simply changing berry size. As a general rule, wines made from smaller berries will have a higher proportion of skin and seed derived compounds (Kennedy, 2002).

Most consumers prefer seedless fruits. Throughout the years, plant breeders have selected seedless tangerines, grapes, and watermelons. To meet consumer expectations, it is important that fruit labeled as *seedless* is effectively free of seeds. Nowadays, there is X-ray and magnetic resonance imaging (MRI)-based methods (see *Nondestructive Measurements in Fruits*) that allow detecting if a tangerine contains seeds. Sometimes, the production of a seedless variety carries problematic "side effects." This has occurred with seedless watermelons, where some fruits develop an internal void, while this defect is less frequent in the traditional seeded watermelon.

Apples and peaches

Physiological disorders are abnormalities of the fruit that are not associated with diseases or insect pests. They can appear during the growing season or after harvest during storage, and affect the appearance and usability of the fruit. Some physiological disorders affecting apples are watercore, sunburn (sunscald), scald (common scald or superficial scald), bitter pit, internal browning (brown heart), and mealiness. Among them, bitter pit and mealiness are probably the best known by most consumers. Bitter pit reduces the fresh-market quality of fruit. It is recognized as an abiotic disorder found in all areas of the world where apples are grown. Bitter pit is influenced by climate and orchard cultural practices. Symptoms consist of small brown lesions of 2–10 mm in diameter in the flesh of the fruit. The tissue below the skin becomes dark and corky. Cultural practices that reduce the incidence of bitter pit are annual bearing, moderate tree vigor, smaller fruit size, calcium sprays, summer pruning, and harvesting mature fruit (Andris et al., 2002).

Horticultural produce must be stored under refrigeration to maintain freshness and reduce decay development. However, low-temperature disorders, chilling injury classified as internal breakdown, limit the storage life of produce under refrigeration. According to Lurie and Crisosto, (2005), chilling injury in peaches and nectarines manifests itself as fruit that are dry and have a mealy or wooly texture (mealiness or woolliness), or hard-textured fruit with no juice (leatheriness), fruit with flesh or pit cavity browning (internal browning), or with flesh bleeding (internal reddening). These authors mentioned a "killing temperature zone" comprehended between 2.2°C and 7.6°C, which must be avoided. Peach maximum storage life can be achieved near or below 0°C, depending on the soluble solids content of the fruit.

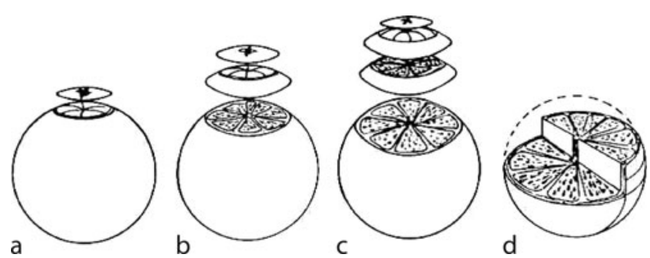
Two well-known textural disorders, mealiness in apples and wooliness in peaches and nectarines, diminish the quality of affected fruit in the fresh market. Both disorders share a lack of juiciness that is perceived when the fruit is chewed, and both of them are negative textural attributes because consumers systematically dislike them. According to Arana et al. (2004), there is a correlation between firmness and juiciness in apple, and this explains why firm apples are usually not mealy. The foregoing correlation makes mealiness detection based on firmness measurement feasible. Firmness (see *Fruits, Mechanical Properties and Bruise Susceptibility*) is one of the aspects of vegetable tissue texture. When a consumer bites a firm apple, the pressure of his teeth breaks cell walls, releasing juice. Nevertheless, when a soft apple is chewed, the pressure exerted by the teeth deforms instead of breaking the cell walls of the apple flesh tissue, and no juice is released, implying that it is a mealy apple.

Citrus fruits

We can highlight three physiological disorders affecting citrus fruits: freeze damage as a potential accident in all citrus species, puffiness in tangerines, and sheepnosing in grapefruit.

The symptoms of freeze injury are principally due to membrane damage. This applies to both the tough carpellary membranes around the individual segments, to the very frail vesicular membranes of the juice sacs, and of the individual cells within the juice sacs (Miller et al., 2006). Initially, frozen areas within the fruit tend to be wet and mushy with the normal radial arrangement of the segment membranes distorted by the action of the formation of ice crystals. At this stage, frozen fruit cannot be mechanically separated from sound fruit. The injured portions dry out within 4–5 weeks. A completely frozen fruit never shrivels because there is no membrane to be pulled inward (see *Shrinkage and Swelling Phenomena in Agricultural Products*). The water diffuses to the outside leaving hollow dried up areas within apparently sound fruit (see *Water Effects on Physical Properties of Raw Materials and Foods*). The severity of the freeze damage is determined by the total volume of desiccated or mushy tissue, following the procedure shown in Figure 1. Lorena Falcone Ferreyra et al. (2006) studied the effect of freeze injury on carbohydrate metabolism and fruit quality in Valencia oranges. They suggested that freezing temperatures provoke a notable metabolic switch in citrus fruit toward a fermentative stage, resulting in low-quality fruits.

Puffiness, also known as "floating skin" or "floating peel," is a weakening and disintegration of the albedo tissues which is characteristic of mature tangerines. The rind becomes thick and separates from the pulp (segments), creating an air gap between the peel and the segments. Floating skin makes the fruit very susceptible to damage during picking and packing, due to punctures and fissures around the calyx. This can cause severe harvest and



Quality of Agricultural Products in Relation to Physical Conditions, Figure 1 To evaluate freeze damage in oranges, first cut a thin slice off the stem to expose the flesh (**a**). Then remove a 0.64 cm slice and examine the orange (**b**). If damage does not extend below this 0.64 cm slice, the fruit automatically grades No. 1 as far as internal quality is concerned. If some damage is noted, make another 0.64 cm cut (**c**), and depending on the extent of the damage noted, the fruit is graded No. 1 or No. 2. Additional cuts may be made as needed to determine the full extent of damage-down to the middle of the orange (**d**) and, in some cases, even lower. Inspectors must balance the area of damage with its depth. A 10% tolerance is allowed on fruit graded for the fresh market. Oranges for concentrate must be "wholesome." (Miller et al., [2006]).

postharvest losses. Moreover, there are some markets, paradigmatically in Japan, where puffy tangerines are not acceptable. In these markets, the detection of a single puffy tangerine usually carries the rejection of the whole carton, and even of the whole pallet. Nowadays, it is technically feasible to detect puffy tangerines using techniques such as X-ray computer vision, MRI, or mechanical firmness assessment (see *Nondestructive Measurements in Fruits*). Occurrence of puffiness in some tangerine varieties is a usual phenomenon; in fact, this peel alteration can affect up to 50% of harvested fruit under the worst conditions (Gutiérrez et al., 1999).

Misshapen, sheepnosed fruit is consistently among the top five causes of fruit elimination at the packinghouse (Ritenour et al., 2003). Sheepnosing, or stem-end taper, is often associated with thick, puffy, or coarse rinds of relatively large fruit. Figure 2 shows some typical sheepnosed or pear-shaped grapefruits. Online detection of misshapen grapefruit at the packinghouse is possible using machine vision technology, i.e., with one or more video cameras that inspect the fruits (see *Image Analysis in Agrophysics*).

Finally, it is important to remark that consumers consider "easy-to-peel" as a quality attribute of utmost importance for tangerines.

Tomato

Tomatoes are consumed both fresh and in various processed foods, with more than 65% of the world tomato production being processed (Moraru et al., 2004). The most relevant quality attributes of tomatoes vary depending on their intended use: taste, appearance, color, and handling characteristics are crucial for fresh-market

Quality of Agricultural Products in Relation to Physical Conditions, Figure 2 Picture taken in a citrus packinghouse in Florida (USA), in 2003. The fruit handled on the date was red grapefruit. Note the defect known as "sheepnosing" or pear-shaped grapefruit in the fruits picked off the roller conveyor. Only the far-right grapefruit is of correct shape.

tomatoes; viscosity and soluble solids content are the most important attributes for triturated or sauce-processing tomatoes (Schuch and Bird, 1994); firmness and skin resistance are the most relevant properties in quality characterization of whole-peeled canned tomatoes (Arazuri et al., 2007). Depending on their industrial use, tomato varieties are classified into two groups: peeled and concentrated varieties. Peeled tomato requires oblong-shape varieties and high quality tomatoes with total absence of mechanical damages. Tomato processing companies are interested in developing varieties which carry oblong, almost square-shaped fruit, in order to pack them more efficiently. For example, some companies might be interested in developing extremely elongated tomatoes shaped like cucumbers. These fruits would be very advantageous when preparing sliced tomatoes for hamburgers, as less ends would have to be thrown away. For the larger fresh-market slicing tomatoes, the ideal is a high locule number (van der Knaap and Tanksley, 2003).

Potato

Physiologically mature potato tubers have high starch and protein levels and low respiration, water content, and sugar levels. Carbohydrates content of tubers can reach 85% of dry matter. Starch content represents usually over 95% of carbohydrates. At harvest, the content of reducing sugars (glucose, fructose) is usually very low (about 0.5%), but it increases during storage, depending on temperature conditions and mechanical damage (impacts, injuries, etc.) suffered by the tuber.

French fries manufacturers prefer long-oval or long tuber with a length of at least 50 mm. For the production of crisps (chips), round tubers are required with a diameter range of 40–60 mm. Potato varieties for frying must absorb little oil, show golden color, and have a crisp and firm texture. If the dry mater content (Table 3) is too low, the French fries or crisps will be too soft or too wet, whereas if it is too high, the French fries will be too hard and dry and the crisps too brittle. Chip color is a very important factor in determining consumer acceptability of potato chips or crisps. The browning of chips is primarily the result of the Maillard reaction which occurs between reducing sugars and amino compounds during

Quality of Agricultural Products in Relation to Physical Conditions, Table 3 Quality requirements for processing potatoes (Netherlands Potato Consultative Foundation [NIVAP Holland])

End product	Dry matter content (%)	Maximum reducing sugars content (% of fresh weight)
French fries	20–24	0.5
Potato chips or crisps	22–24	0.3
Dehydrated potato products (flakes, granules, flour)	>21	0.3

the frying operation at high oil temperature, with the amount of reducing sugars being the limiting factor.

The sugar content in potato tubers depend on many factors, both hereditary and environmental. Tubers of most chipping cultivars stored at temperatures below 9°C for sprouting control accumulate appreciable amounts of reducing sugars. These sugars are the result of starch hydrolysis. Due to the low respiration rate associated to the low storage temperature, sugars are not oxidized ("burned"), resulting in potatoes with a sweet taste. High sugar concentrations in the tubers result in an objectionable sweet flavor in baked or boiled potatoes and result in dark colored chips and French fries. The dark product in fried products is also bitter-tasting. Potatoes that are destined for use as chips or fries are usually taken from cold storage and reconditioned at 12–16°C for a period of 1–2 weeks to reduce the sugar level and make the potatoes satisfactory for processing. The effect of a warmer storage temperature is that sugars are oxidized at a higher rate compared to cold storage conditions.

Potatoes can present several internal defects, like hollow heart, internal discoloration, and "greening." Hollow heart (an irregular hole at the center of the tuber) is caused by excessively rapid growth. Internal discoloration may be caused by improper field or storage conditions, freezing or disease; each causes a different type of discoloration. Potatoes with severe internal discoloration should not be eaten. After harvest, potatoes should be kept away from natural or artificial light because exposure to light causes a green coloring – "greening" – to the tubers. Sometimes only the skin is affected, but greening may penetrate the flesh. The green portions contain the alkaloid *solanin*, which causes a bitter flavor and may have a poisonous effect when consumed in great quantities.

Summary

Grain and horticultural produce are irreplaceable in human nourishment. According to the opinion of some scientists, for a reasonable utilization of the planet resources we should be as vegetarian as possible. Eating beef is little efficient, as a bovid transforms into protein only the 5% of the protein it consumes. Chickens are more efficient, since their protein conversion rate is of 25%. From this point of view, it seems more reasonable to consume the vegetables directly. This does not imply that livestock industry should disappear since livestock provides us with products such as wool, milk, eggs, etc., which are of great nutritional interest and cannot be obtained from plants.

Although crucial vegetal foods in human nourishment as legumes and oilseeds have not been addressed here, some ideas have been presented on quality of emblematic grain and horticultural produce. An interesting reflection is that the quality of a product depends on the intended use. With the purpose of protecting public health and guaranteeing trade transparence, official organisms dictate quality or marketing standards for agricultural products.

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