CHAPTER 2. PHYSICAL PROPERTIES, GRADING, AND SPECIALTY GRAINS
SELF-EVALUATION

1. What is the main aim and advantages of grain grading?

The main objectives of the classification systems are: facilitate the fair commercialization of grains, standardize grain quality in terms of economic value, provide information related to grain quality for storage and further processing, provide information that can be related to yields of products and byproducts (milling yields, end-product quality etc.)

2. What are the main differences between grade and class?

Grade is an indication of quality and grain health condition whereas class is related to the potential use or functionality of the grain (color, gluten type, hardness etc.).

3. Why test weight is one of the most important criteria for grain grading (grade and class)? What is the conversion factor of lb/bu to kg/hL? How much maize with 56 lb/Bu can you place in a storage bin with the following dimensions: 20 m wide, 10 m height and 50 m long? How many tons of oats with 30 lb/bu can you place in the same storage bin? Calculate results in lb, kilograms and metric tons.

Test, bushel or volumetric weight is the most critical criteria to determine grade and class. Test weight is closely related to the true grain density and therefore is affected by grain condition, grain texture and even grain protein content. This measurement is very useful because insects, molds and/or sprouted or heat-damaged kernels had a lower test weight when compared with healthy or sound counterparts. On the other hand, vitreous or corneous grains with slightly higher protein content are usually denser. Lots of grains with higher moisture content usually have a lower test weight because the water has a density of 1 g/cm^3 whereas the starch 1.6 g/cm^3. The conversion factors of pounds per Winchester bushel (2,150.42 in^3) and pounds per imperial bushel (2,219.36 in^3) to kg/hL are 1.297 and 1.247, respectively.

Maize: 56 lb/bu. Volume of storage facility (20 m wide, 10 m height and 50 m long = 10,000 m^3

56 lb/bu x 1.297 conversion factor = 72.632 kg/hL or 0.726 ton/m^3

0.726 ton/m^3 x 10,000 m^3 = 7,260 Ton in the storage facility or 7,260 Ton x 1000 kg/ton = 7,260,000 kg in the storage facility or 7,260,000 kg x 2.2 lb/kg = 15,972,000 lb

Oats: 30 lb/bu . Volume of storage facility (20 m wide, 10 m height and 50 m long = 10,000 m^3

30 lb/bu x 1.297 conversion factor = 38.91 kg/hL or 0.389 ton/m^3

0.389 ton/m^3 x 10,000 m^3 = 3,890 Ton in the storage facility or 3,890 Ton x 1000 kg/ton = 3,890,000 kg in the storage facility or 3,890,000 kg x 2.2b/kg = 8,558,000 lb

4. Explain the reason why test weights of whole oats and dehulled groats are quite different?

The test weight of whole oats (approximately 58 kg/hL) is considerably lower compared to the test weight of dehulled groats (approximately 78 kg/hL) because the husks or glumes occupy volume that include air inclusions and the glumes rich in fiber had lower density compared to the starch rich endosperm. Therefore, the groats had 1.3 more apparent density compared to whole oats.

5. How can you identify frost-, insect-, mold- or sprout- damaged kernels?

Frost affected kernels have a lighter coloration and usually lower thousand-kernel weight because because they do not fill properly in the field or are badly shrunken. Frost-damaged wheat and barley have a waxy appearance and can have light green, brown or even black colorations. In these cereals, the pericarp is generally wrinkled and blistered in the dorsal and crease parts of the caryopsis. Frost-damaged oats usually have a blackened germ that is easily recognized when the caryopsis is longitudinally cut.

Insect infested kernels are easily identified because they have perforation or web-like material that aggregate grains. Insects puncture grains for reproductive and feeding purposes and the web-like material or silken threads are characteristics of moth infestations.

Mold-infested grains are easily detected because of the color change on the pericarp and germ tissues (black tip or blue eyed kernels). These kernels usually acquire a dirty off-coloration. Molds have potent enzymes that degrade reserve tissues of the *germ* and endosperm. Mold infested kernels have lower test weight and important changes in starch, lipids and proteins. The amylases, lipases and proteases breakdown starch, lipids and proteins, respectively. As a result, mold-damaged kernels have higher values of reducing sugars and fat acidity. Grain inspectors are trained to detect mold infested or weathered kernels by a visual inspection and the moldy stench of infested grains.

Sprouted kernels are easily identified because they contain rootlets and in some instances even acrospires. These grains have high-diastatic, lypolitic and proteolytic activity due to generation of amylases, lipases and proteases, respectively. Therefore the starch, lipids and proteins are hydrolyzed or damaged generating higher amounts of reducing sugars, free fatty acids and free amino nitrogen, respectively.

6. What is a heat-damaged kernel? What are the main causes of heat damage? Why is heat damage considered as one of the most important criteria for assigning grade?

Heat damage is produced by high temperature drying or faulty storage. Heat-damaged kernels are identified by a darker color and appearance. Most are generated when grains are stored at high moisture and therefore have high respiration rates. The high grain temperature and generation of soluble sugars due to the activation of intrinsic enzymes produce Maillard reactions and off-colors and in some instances the loss of seed viability. It is one of the most important criteria for assigning grade because heat damaged kernels contain high enzymatic activity and hydrolyzed lipids, starch and proteins. As a result heat-damage kernels have high diastatic activity that greatly affects functionality especially in the wheat milling and processing industries.

7. What are the main physicochemical characteristics and main food uses of the three different classes of wheat?

The main physicochemical characteristics of the three major classes of wheat are depicted in the following table.

Wheat	Test	1,000 kernel	Protein/Gluten	Functionality

Class	weight (kg/hL)	weight (g)	Characteristics	
Hard	80.9	20-32	Protein: 10.5 to 14%. Gluten: good strength and extensibility.	It possesses an intermediate endosperm texture and yields gluten adequate for the fabrication of an assort of yeast leavened baking breads and products.
Soft	77.8	30-40	Protein: 7.5 to 10%. Gluten: low strength and very high extensibility.	It possesses a floury endosperm and produces a gluten adequate for the fabrication of cookies, cakes and products leavened with chemical agents or baking powders.
Durum	74.0-80.0	20-60	Protein: 10.5 to 17%. Gluten: very high strength and very low extensibility.	It generally contains a yellow vitreous endosperm suitable for the industrial production of long and short pastas.

8. **Why the 1,000 kernel weight is a physical grain property highly related to milling yields? What kind of instrument is used to perform the 1,000 kernel weight measurement?**

The 1,000 kernel weight is frequently used because within grain is an excellent indicator of grain size and proportion of endosperm to germ and pericarp tissues which is related to dry and wet-milling yields. The industry selects uniform and large kernels because they contain a higher proportion of endosperm or starch to germ and pericarp tissues. The test is simple, practical and fast and is usually performed using an automatic seed counter.

9. **What are the main physicochemical characteristics of long, medium and short rices? What are the main criteria used to differentiate these classes of rice?**

Rice is generally classed according to size in large, medium and short types. These average rough or paddy rices have an average test weight of 56, 58.5 and 60 kg/hL, respectively. The dimensions of large paddy rice are 8.9 to 9.6 mm length and 2.3 to 2.5 mm width with a

length/width ratio of 3.8 to 3.9:1. The medium paddy rice has a length, width and length/width ratio of 7.9-8.2 mm, 3.0-3.2 mm and 2.5-2.6:1, respectively whereas the short paddy rice 7.4-7.5 mm length, 3.1-3.6 mm width and 2.1 to 2.4:1 length/width ratio. This last measurement is used as one of the most important criteria for classification. The average length and width is calculated after the longitudinally arrangement of 10 caryopses positioned length wise or wide wise.

10. What are the main differences between waxy and regular endosperm rices in terms of starch composition, culinary properties and food uses? How can you differentiate a waxy from a regular endosperm rice?

The main difference between waxy and regular rices is in the starch composition. Regular rices contain about 75% amylopectin and 25% amylase whereas waxy rices, also referred to sweet or glutinous are characterized by opaque endosperms in which the starch is practically 100 amylopectin. Most waxy types are classified as short rices and have a low gelatinization temperature and relatively low amylograph peak, hot paste and cool paste viscosities. When cooked they tend to lose their shape and are sticky or glutinous. Waxy rices are used to prepare Sushi. The waxy rice can be differentiated from regular rice by analyzing their starch composition, viscoamylograph behavior or by the rate of water absorption during cooking schedules. Waxy rices tend to absorb more water during cooking compared to regular rices.

11. Why aromatic rices have special flavor and aroma?

Aromatic rices, such as Basmati, Jasmine and Texmati, possess a characteristic flavor and aroma once cooked because contain a major compound that imparts the typical nut-like or popcorn aroma and flavor. The compound has been identified as 2-acetyl-1-pyrroline.

12. What are main differences between dent and corneous maizes in terms of the form of the caryopses and endosperm texture?

The main difference in the form between dent and flint or corneous maizes is in the form of the kernel´s crown. The crown of dent maize has a straight form and a characteristic indentation whereas the crown or top part of flint maizes a round configuration without the indentation. Most dent maizes have a soft or intermediate endosperm texture whereas most flint maizes a harder endosperm or higher ratio of hard to floury endosperm. The typical example of a corneous maize is popcorn that contains the round shaped crown with a 100% vitreous endosperm.

13. What are the ideal physical properties of popcorn? Investigate the popping expansion rate of a good popcorn.

Popcorns are special kinds of flint kernels with high proportions of translucent, flinty or vitreous endosperm that give high expansion rates. The popcorn has a test weight of 82-83 kg/hL, true density of 1.37 g/cm^3, 1000 kernel weight of 140 g, and average length, width and thick of 8.3, 5.6 and 4.3 mm, respectively. Most commercial popcorn has a 30 to 40 fold expansion volume. The pericarp and outer layers of the kernel participate directly in the popping action by serving as a pressure vessel enclosing the endosperm.

14. Where are located the blue pigments in blue maize? What kinds of phytochemicals confer these pigments?

The aleurone layer of the endosperm contains the pigments that impart the blue appearance. These pigments are classified as anthocyanins that are known as potent antioxidants. These pigments similar to the found in red wine have important positive health implications because decrease oxidative stress and prevent most chronic diseases.

15. Explain the reason why quality protein or high-lysine maize is nutritionally superior compared to regular maize counterparts. Investigate how opaque-2 maize was transformed into quality protein maize. What other cereals have high-lysine types?

Quality protein maize has the opaque-2 gene that significantly increases the amount of lysine and tryptophan compared to regular counterparts. The higher level of these limiting amino acids improves protein quality, nitrogen retention (biological and net protein utilization values) and growth in humans and monogastric animals. The PER value of QPM is twice as much compared to regular maize and therefore is recommended for infants who depend on cereals as the only source of protein. The opaque 2 corn was transformed into an array of QPM materials by incorporating modifier genes that significantly improved the hardness and agronomic performance of the crop. The breeding process conducted at CIMMyT took at least 12 years. Today high yielding hybrids are experimentally used in Brazil, Mexico and other countries while open pollinated varieties are grown in Africa and Central America. The future of QPM looks promising both in developing and developed countries.

16. What are major differences between two-rowed and six-rowed barleys and the main difference between malting and feed barleys?

Six-rowed barleys produce six kernels per row (3 kernels per row side of the spike) whereas two-rowed barleys only two kernels. The kernels of six rowed barleys are usually smaller or have lower 1,000 kernel weight compared to counterparts from two-rowed varieties. The malting industry uses both types of barleys but two rowed barleys are preferred because bear larger kernels. Malt and feed barleys differ in protein content and diastatic activity. The malting types usually have a lower protein but higher starch contents that upon germination yield more fermentable sugars. Generally, malting barleys contain 9.5 to 12.5% protein. On the other hand, feed barleys are within the four most used cereals for animal feed. The protein of these barleys varies from 12.5 to 17%.

17. What are the three major classes or grain sorghum? Which class is the most planted worldwide?

The USA Federal grain inspection recognizes four classes of sorghum: brown or high tannin, yellow or red, white and mixed. The most popular worldwide is yellow or red. Brown sorghums, also known as bird-resistant or tannin sorghums, posses a testa that contains condensed tannins. These are more resistant to sprouting in the field, bird damage, weathering, molds and other phytopathogens. However, tannins act as antinutritional compounds decreasing protein digestibility and the overall nutritional value of the grain. Generally speaking, tannin sorghums have 85% of the nutritional value of other sorghums and maize. White sorghums possess a white pericarp without pigmented testa and are widely planted for direct human food uses in India and Africa. The most popular class of red or yellow sorghums is widely used as a substitute for maize in animal feeding. These sorghums do not contain significant amounts of condensed tannins. The mixed sorghum class contains more than 10% of other classes and therefore do not meet any of the specifications of the other three main classes.

18. Why Brown or type III sorghums have more resistance to sprouting, molds, birds and other biotic agents? What is the basis of identification of tannin sorghums using chlorine solution?

Because brown sorghums contain significant quantities of condensed tannins that act as antinutritional factors and as enzyme and mold inhibitors. These sorghums are bird resistant because they have a bitter and different flavor that is disliked by birds. In addition, the tannins bind dietary proteins and digestive enzymes lowering the overall nutritional value of the diet. The Clorox test, which uses a hot solution of potassium hydroxide and sodium hypochloride are used to detect type III sorghums. The principle is that the hot potassium hydroxide hydrolyzes the fiber rich pericarp so to allow the reaction of the sodium hypochloride with the tannins present in the testa. The chloride solution and high pH stains black the condensed tannins.

19. Why ergot-contaminated rye is heavily penalized by grading systems? How grain inspectors recognize ergot-contaminated rye?

Because the parasitic mold known as Ergot (*Claviceps purpurea*) produces a toxin highly toxic to humans (Ergotism). The consumption of alkaloids ergotamine and ergotine produces the syndrome known as *"St. Anthony´s Fire"*. The consumption or ergot contaminated products produce the symptoms of hallucinations, gangrene, and paralysis and in some instances death. The ergot contaminated kernels are easily recognized because the parasitic mold produces larger kernels with a strong dark coloration.

20. How grain inspectors differentiate wild from commercial oats?

Commercial oats (*Avena sativa* or *Avena byzantina*) differs from wild oats (*Avena fatua*) mainly in the form of the awns. Wild oats produce twisted instead of straight awns and has pubescence in the basal or germinal part of the caryopsis.

21. What is the main reason why among cereals oats possess the lowest volumetric or test weight?

Because oats is a naked caryopsis in which the light weight husks or glumes occupy volume that include air. The relatively low density of the glumes and air lowers the apparent density or test weight. The removal of the glumes increases the test weight of oats by more than 30%.