LIME COOKING PROCESS: NIXTAMALIZATION
FROM MEXICO TO THE WORLD

Basic concepts

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This basic manual on nixtamalization has been developed by the contribution of many authors: Natalia Palacios[1], Mario Rodriguez[2], Gricelda Vazquez[3], Magda Carvajal[2], Aide Molina[1], Luisa Cabrera[1], Aldo Rosales[1], Ma. de la Luz Marrufo Díaz[3] and Edith Domínguez Rendón[3].

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Introduction

Maize is the major food staple in Africa and Central America with high per capita consumption (103 kg/year), and contributes 31% of calories and 28% of protein supply. Maize was introduced in Africa by the Portuguese sailors in the 16th century. Due to its wide adaptation to diverse environments, low rate of damage by birds unlike sorghums and millets, and its relative ease of growing, storing and processing, white kernel maize rapidly replaced the indigenous cereals in the fields and in diets. This pattern of use of maize in Kenya and other east African countries mirrors that of Mexico where maize originated. Paradoxically, Mexico exported maize seed to Africa but not the technologies for its utilization. Whereas Mexicans have in excess of 600 products from the maize plant, African countries can hardly count more than 10 uses of maize. Maize in African countries in general is prepared for consumption as kernels either whole or decorticated. Whole kernels are prepared for consumption by boiling in admixture with beans and then stewed with potatoes or green vegetables. This mixture is referred to as Githeri by communities in Central Kenya who are its main consumers. In some communities, the mix is boiled with soda ash or ash infusions, which make the kernels turn yellow – they are said to be tastier than those boiled with plain water. The decortication is carried out by three methods: 1) Wet decortication by light pounding in a mortar with pestle and winnowing off the detached pericarp (mostly by communities in Eastern Kenya especially the *Kambas)*, 2) Machine decortication by using mechanical abrasion (industrial decortication for commercial purposes) and 3) Boiling in alkaline infusions from ashes obtained from maize cobs, bean trash etc. practiced by the ***Kalenjin*** community). In urban areas, maize is also milled into meal of different extraction rates ranging from about 70 – 100%, and used for preparation of principally ugali or sadza and sometimes porridge. Whole grain green maize is often roasted or boiled on cob for consumption. Maize meal consumed in the rural areas is supplied from milling on small scale (usually contractual milling between the miller and the domestic consumer) using small village hammer mills, otherwise commonly referred to as ***posho mills.*** These mills are widespread in the rural villages and normally produce whole maize meal.

Mexico as the origin of maize has longer experience with maize and has therefore developed diversified food products, mainly derived from lime-cooking process, called nixtamalization. It is a process that involves cooking and steeping maize kernels in calcium hydroxide (lime). More than 300 food products commonly consumed in Mexico alone are derived from nixtamalized maize.

Nixtamalization provides nutritional benefits, including: 1) Reduction in pellagra disease risk, due to the improved niacin bioavailability, 2) Increasing calcium intake due to its absorption by the kernels during the steeping process with caustic alkali, 3) supply of dietary fiber by increasing resistant starch content in the food products, and 4) Significantly reducing mycotoxin

levels in kernels. Nixtamalization provides these nutritional and health benefits especially where maize is the dietary staple and the risk of aflatoxins is high.

The limited food uses of maize African countries in turn limits per capita consumption and leads to reduced demand, reduced markets for farmers produce. Limited processing reduces the maize value chain and denies African countries the opportunity to industrialize as its industries are largely agriculture driven.

Thus in addition to the nutritional benefits of nixtamalization, commercialization of nixtamalized products is benefit for the extended shelve life of the food products, generating income and market opportunities for the communities.

The thermo alkaline process (cooking) is governed by the amount and quality of the lime, cooking temperature and amount of water (that determines the lime solubility). Usually, this process is done under over saturate conditions. The reported values for the calcium hydroxide (cal, lime) are between 0.5 to 3%. This process is carried out in open vats that do not have any thermal skin to reduce the loss of heat, the mixture of the nixtamal is manually, and the end of the cooking time is determined by the manual removing of the pericarp or by the moisture content.

Figure 2 shows the block diagram of traditional nixtamalization process used to obtain dough (masa) and tortilla. This process uses maize, water, and lime as raw material.

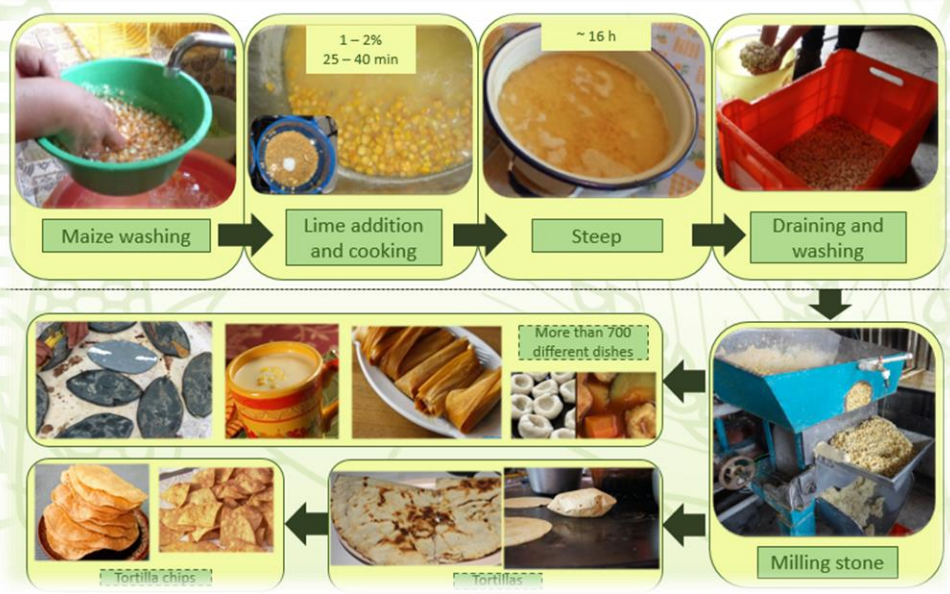

Figure 1. Traditional nixtamalization process.

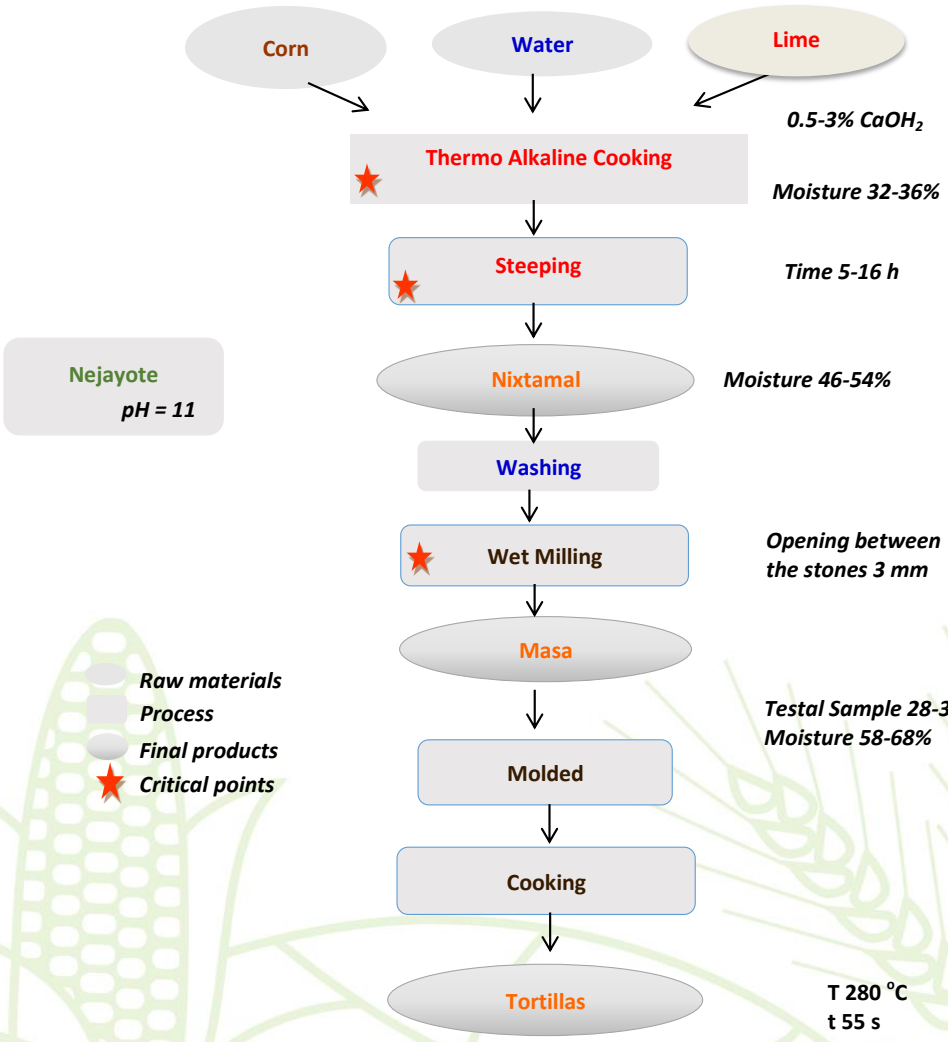

Figure 2. Diagram of the traditional nixtamalization process.

Nutritional benefits of nixtamalization:

- ✓ Reduction in pellagra disease risk, due to the imrpoved niacin bioavailability.
- ✓ Increasing calciumm intake due to its absorption by the kernels during the steeping process.
- ✓ Serving as a source of dietary fibre by increasing resistant starch content in the food products.
- ✓ Slightly decrease the levels of phytic acid, an inibithor ori ron and zinc absorption.
- ✓ Increases the calcium/phosphorous ratio which makes the tortilla nutritionally similar to milk.
- ✓ Significantly reduce mycotoxins in kernels.

Lime-cooking ingredients

Maize kernels

In principle, any type of maize can be nixtamalized. However, the efficiency (time and cost wise) and the quality of the final food products will be affected by the physico-chemical characteristics of the maize. In general semi-hard to hard kernels and intermediate size are the preferred ones. Depending on consumer preferences, grain color is also consider an important quality trait considered. In the grain quality section, a detailed description of the kernel quality traits and methods to determine them is presented.

Water

Water is the solvent used for $Ca(OH)_2$ and plays an important role during the cooking, steeping, and milling steps of the nixtamalization process. During the cooking process water allows the lime solubilizaton, and causes swelling of starch grains during cooking and steeping processes due to simultaneous water absorption and diffusion in the kernel. Usually for cooking process 1:3 maize to water ratio is used.

Kernels absorb about 28-30 % water during the cooking process and 5-8 % more during the steeping (McDonough et al. 2001, Rooney and Suhendro 2001). That allows the milling process to obtain masa when pericarp. Germ and endosperm are integrated. On the other hand, it has been calculated that due to the sweeling of corn grains their sizes increases about 1.5 times their original size. Water uptake is a kinetic process which is governed by physical changes in kernel components. These changes depend on lime concentration, pericarp thickness and endosperm type (Laria et al. 2005). Nixtamal moisture of 50 % has been reported to give masa that has acceptable plasticity and machinability (Gomez et al. 1989).

Lime: Calcium hidroxyde

The use of calcium hydroxide in the nixtamalization process increases the pH value of the cooking liquor from 7 to 12. The increases in the pH allows the partial pericarp removal and the most important aspect in term of the diet is that increases the calcium content (Fernández-Muñoz et al. 2004). Normally between 1 to 3% of $Ca(OH)_2$ is used.

Lime is the result of a process where calcite is extracted and calcinated to produce CaO and then Ca(OH)2, which is a dry powder obtained by adding water to CaO thereby transforming the oxides into hydroxides. Raw materials could have chemical impurities. Due to the

calcination by fossil fuels and with the addition of water during hydration, certain contaminants could be introduced.

Calcium is the most abundant mineral in the human body, and with phosphorous are the main elements forming the bone. Calcium is a fundamental nutrient implicated in a good number of metabolic processes which provide rigidity to the bones and teeth. It is well known that certain diseases including bone fragility, hypertension, and colon cancer, may be caused by chronically low dietary calcium intake. According to Flynn (2003) point out that increasing of calcium intake higher than the averages consume may have benefits for the development and fortification of bones, and may reduce the risk of osteoporosis in later life.

The incorporation of calcium hydroxide in food such as nixtamalized products have been the most important source of calcium in the daily diet of Mesoamerican people and recently in other countries such as Unites States of America, China, United Kingdom.

According to the Mexican norm NOM-187-SSA1/SCF1 2002, calcium hydroxide must fulfill the following specifications:

Table 1. Calcium hydroxide specifications.

Chemical name	Calcium hydroxide	Calcium oxide
Chemical formula	Ca(OH)2	CaO
Molecular weight	74,10	56,07

And the following physico-chemical properties:

Table 2. Physico-chemical properties.

Specification	**Limit**
Calcium hydroxide or Calcium oxide	90% Minimum
Magnesium hydroxide	5% Maximum
Lead	8 mg/kg Maximum
Fluor	40 mg/kg maximum
Arsenic	3 mg/kg

Traditional nixtamalization process

Thermoalkaline cooking

The traditional nixtamalization process is carried out using between 0.5 to 3 % of lime. Usually the water is heated until boiling point or little below (85-92 ºC), and then the maize kernels are added (beginning of the cooking process). The moisture content is sensed by direct inspection of the pericarp removal. Heat is removed and kernels are steep in the cooking liquor for around 12-16 h.

Steeping

After the cooking time the corn grains are steeping in the cooking liquor for 5 to 16h, and according to Gutierrez et al. (2007) the most important changes in the physicochemical properties occurs.

In this stage, the heating is suspended and the grain is allowed to stand in the cooking liquid (nejayote) for a period of time that varies from 5 to 16 hours until the mixture is cooled (figure 3). The viscosity and color of nejayote varies due to the loss of dry matter formed by the solids leaching of corn kernels (Rojas-Molina et al., 2009). In industrial processes corn grain reaches a humidity range of 46-54% at the end of the steeping stage. At the end of the steeping stage, the nejayote reaches a pH value of 12.5 approximately, and then it is drained. The hydrated corn is washed twice with water and removing the pericarp by rubbing the kernels.

At this point it is important to denote that the calcium and water diffusion into the corn kernels is a temperature-dependent process that is governed by the physicochemical changes of its anatomical structures mainly in pericarp. During the steeping stage the starch of endosperm gelatinizes partially, trialiglycerides and free fatty acids of germ and endosperm are saponified (Bello et al., 2002; Fernández-Muñoz et al., 2002 González et al., 2004; Gutiérrez-Cortez et al., 2007). Additionally, during the steeping stage a significant dry matter loss of the kernels take place; this material is constituted by fractions of pericarp, endosperm and germ (Ortega et al 1986; Almeida-Dominguez et al 1998; Sahai et al 2000; Rojas-Molina et al 2009).

Figure 3. Thermoalkaline cooking and nixtamal steeping.

Washing

After cooking and steeping maize grains are cooled and still remain in the liquid called nejayote (figure 4), the grains are drained off and in order to remove small pieces of pericarp, germ, and endosperm as well as a water-lime liquid grains are washed at least twice. Other important aspect of the washing is the whiteness of the masa and tortilla.

Figure 4. Nixtamal washing.

Wet milling

Nixtamal grinding is done with volcanic stone disk mills (Fumasa, M100, Qto.) (figure 5) in an open system with an impact and/or rubbing effect (McCabe, 1981). The stone disks are maintained with an opening of 3 mm between them and with a constant feed rate provided by the screw feeder integrated into the mill (Gutiérrez-Cortez et al., 2010).

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This step is also critical for the quality of the dough, being heat and moisture the two main factors (figure 6).

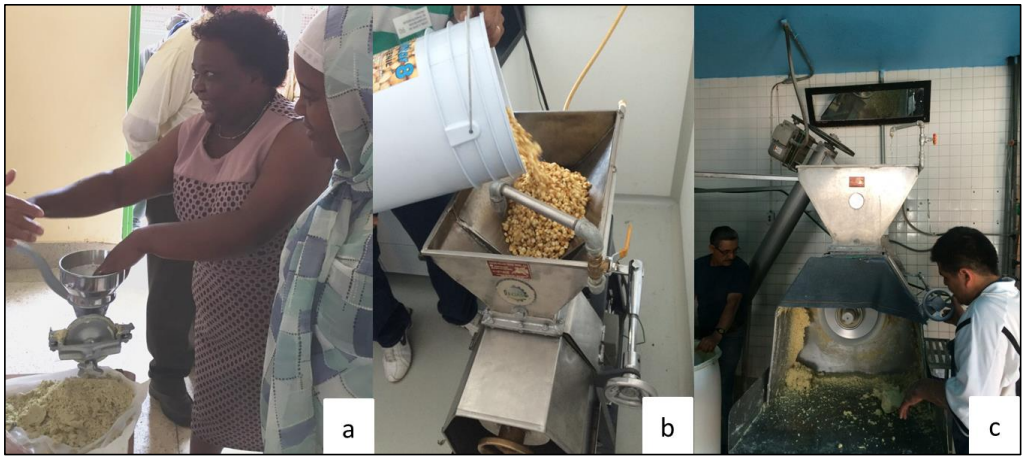

Figure 5. Nixtamal milling. a) Milling with mill disc, b) y c) Milling with volcanic stone disk mills.

Figure 6. Nixtamal dough.

Molded

The wet granules obtained by grinding are hydrated to reach a humidity of 58-60%. Then, the material is molded and homogenized, this mixture is known as dough or masa. Once the dough is obtained portions of 28-35 g are separated to make flat dough disc (tortillas) (figure 7).

Figure 7. Tortilla molded. a) Tortilla pressed, b) Corn tortilla machine.

Cooking

The tortillas are cooked by using a flat iron pan at 280 °C ± 5 °C. Cooking time is 17 seconds for a thin tortilla and a thick tortilla requires 55 seconds approximately (figure 8).

Figure 8. Tortilla cooking.

Figure 9. Maize products.

MAIZE GRAIN QUALITY

Maize grain quality is affected by maize genetics and by the environmental conditions under which the grain is produced, its agronomic management (sowing date, fertilization, water availability, plant density, pest and disease control, etc.) and grain management during storage; these aspects play an important role in grain quality characteristics. These variations and the genetic diversity in Mexico require selection that is based on adequate grain classification according to its physical and chemical properties. In addition, the experience of maize researchers and processors has shown that grain hardness and size, as well as its color, are the primary selection variables for the nixtamalization process (Miranda et al., 2013).

Classifying maize quality by type and grade is fundamental and critical for global grain commercialization and mobility (Serna, 1996). Knowing the quality grade of a maize grain lot leads to better and fairer marketing between buyers and sellers and allows mixing grain lots of the same grade or quality.

Important when monitoring grain quality is the type of sampling that is done, which depends on the objective of the study and on the tests to be performed. In general, the recommendation is to take samples at random and make up composite samples to ensure that the test material is representative.

I. EXTRINSIC QUALITY

To ensure that maize grain is available in the amounts and the quality required norms have been established to help ensure the raw material is safe to consume, to reduce losses during maize storage and processing, and to ensure the production of better quality tortillas. Mexican norm NMX-FF-034/1-SCFI-2002 includes the following specifications regarding the extrinsic characteristics of maize grain (Table 3):

Table 3. Maize grain damage observed upon reception.

Parameter	Grade 1	Grade 2	Grade 3
Broken grain (maximum %)	3.0	3.5	4.0
Impurities (maximum %)	2.0	2.5	3.0
Heat damage (maximum %)	1.5	2.5	3.5
Total damage (maximum %)	5.0	7.0	10.0

Source: NMX-FF-034/1-SCFI-2002.

1.1. Broken grains and impurities

Impurities are any foreign materials that are neither maize grain nor grain particles and that can go through a sieve with round holes measuring 0.238 cm (6/64 of an inch), as well as particles that remain on top of a sieve with round holes measuring 4.76 mm (12/64 of an inch) and that are not maize grains (cobs, branches, leaves, etc.)

Classified as broken grain are all materials that pass through a sieve with round holes measuring 0.476 cm (12/64 of an inch) and that remain on top of a sieve with round holes measuring 0.238 cm (6/64 of an inch), in addition to maize pieces that do not pass through a sieve measuring 0.476 cm in diameter, even though their size is 50% smaller than the size of grain.

The procedure consists of separating and quantifying the broken grains (grains with a part missing) and impurities (any foreign body or material different from maize grain, including cobs and other plant parts, that pass through a sieve with round holes 4.76 mm in diameter), as well as all materials that did not pass through the sieve but that are different from the grain. Measuring these materials requires a balance with a sensitivity of 0.1 g, sieves with round holes 0.476 and 0.238 cm in diameter and a tray at the bottom, plus a Boerner grain homogenizer. A kilogram of maize grain previously divided using the Boerner homogenizer is placed on the pile of sieves; shake the sieves for about one minute using circular movements to separate the impurities or weeds, weed seed, soil, glass, metal, wood, stones, pests and excretions.

Manually remove all materials that did not pass through the 0.476-cm sieve and that are different from the grain and put them in the tray at the bottom. Check the tray at the bottom for the presence of insects and excretions; separate, quantify and report them (Figure 10).

Weigh the contents of the tray at the bottom and determine the impurities according to Equation 1.

$$\%\ \text{impurities} = \frac{\text{weight of the impurities (g)}}{1000\ \text{g}} \text{x}\ 100 \qquad \text{Eq. (1)}$$

Take the grain particles that remain on the 0.238 mm sieve, as well as the maize pieces that did not pass through the 0.476 mm sieve but whose size is smaller than 50% of grain size. Quantify them according to Equation 2.

$$\% \text{ broken grains} = \frac{\text{weight of broken grains (g)}}{1000 \text{ g}} \text{ x } 100 \qquad \text{Eq. (2)}$$

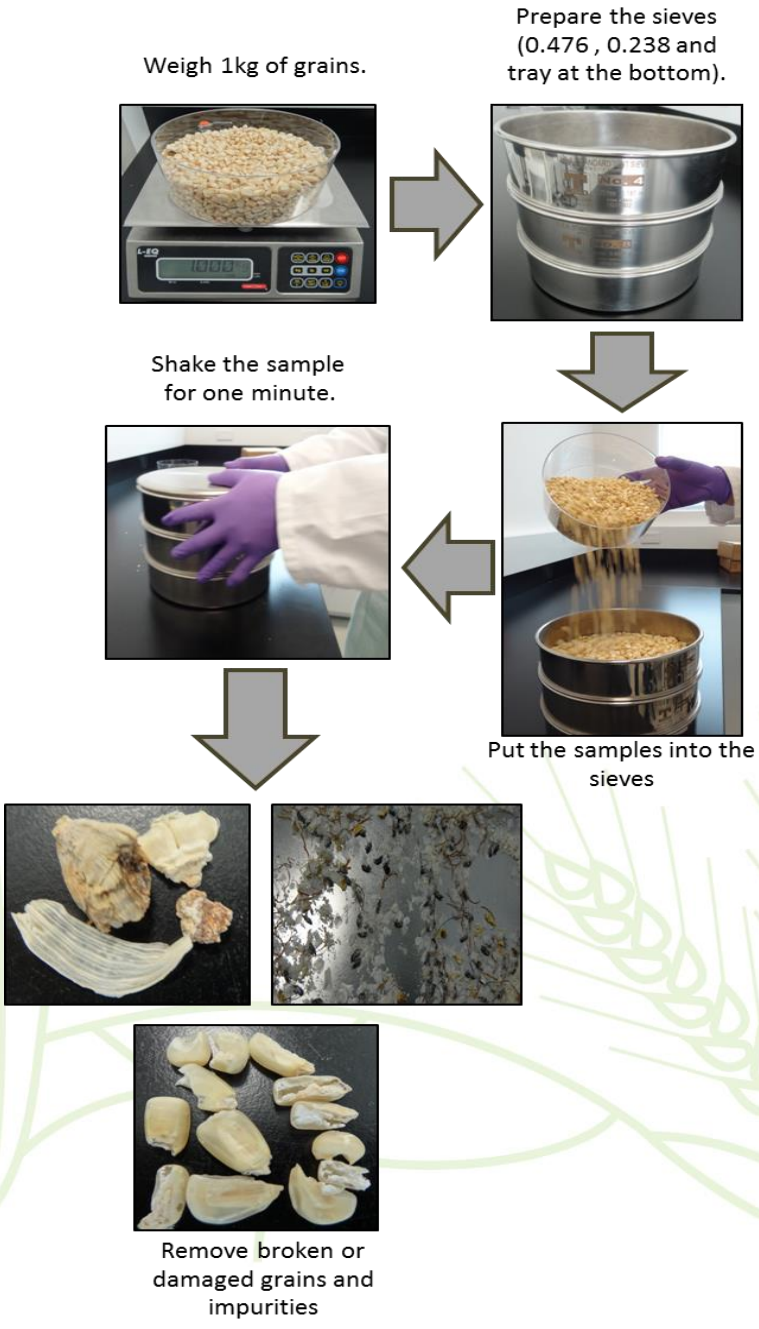

Figure 10. Flow diagram showing how broken maize grains and impurities are classified.

1.2. Damaged grains

Damaged grains are whole grains whose parts have undergone physical or chemical alteration (whether external or internal) as a result of fungi, heat, insects, rodents or weather conditions (Figure 11). Fungi and other microorganisms may develop on the surface (pericarp) of the grain, in the germ or embryo, and/or on the rest of the grain (endosperm), and the effect may be total or partial. These microorganisms can occur in the field or in storage; they are characterized by a bluish, blackish, greenish, orangish or yellowish color and may appear slimy or cottony. Overheating the grain during drying will make the whole grain or sometimes only the germ or embryo (center of the grain) turn dark brown or black.

Insect-damaged grains generally present holes or tunnels made by insects in the field and/or in storage. Grains that have been attacked by rodents show their toothmarks or bites, while grains damaged by weather conditions such as rain, hail or drought, are shrunken, germinated, stained or rotten, among other things (NMX-FF-034/1-SCFI-2002).

Dissecting forceps and an analytical balance are required to determine the percentage of damaged grains. To do this, weigh 100 g of clean grain that is free of impurities; then manually separate the grains that show insect, heat, fungal or other types of damage from the rest. Using the balance, calculate, according to Equation 3, the percentage of grains that were identified as damaged.

$$\%\ \text{damaged grains} = \frac{\text{weight of damaged grains (g)}}{100\ \text{g}}\ \text{x}\ 100 \qquad \text{Eq. (3)}$$

NOTE: Repeat this procedure for each type of damage observed and report them separately.

Figure 11. Types of damage most commonly observed on maize grain: a) Spots; b) Broken kernels; c) Germinated kernels; d) Fungal damage; e) Rotten kernels; f) Holes; g) Shrunken kernels.

1.3. Aflatoxins

Aflatoxins and fumonisins are among the mycotoxins found on maize grain. Fumonisins are produced by the fungus Fusarium. Aflatoxins are secondary metabolites produced by the fungi Aspergillus flavus and Aspergillus parasiticus. The main fumonisins to test for are B1, B2, G1 and G2; the name of each fumonisin begins with the first letter of the color (either blue or green) of the flourescence it emits.

It is important to detect these mycotoxins because they are toxic and carcinogenic substances found mainly on cereals such as maize, as well as peanuts, cotton seeds and nuts. Some of these cereals are staple food crops: for example, maize is one of the main food sources in Mexico, where it is eaten in the form of different food products, such as tortillas. Thus in Mexico, aflatoxin-contaminated maize is a potential health risk for the population. According to Official Mexican Norm NOM-188-SSA1-2002, maize grain should contain a total of no more than 20 µg kg-1 of aflatoxins.

To quantify aflatoxins, mix the samples with a methanol extraction solution; then dilute the extract and filter it. Add the extract to the immunoaffinity columns which will retain the aflatoxin-specific antibodies. Rinse the column with water to remove any impurities; then elute with HPLC grade methanol (because aflatoxins are soluble in it) and with the aid of a bromine solution (used as a developer), the aflatoxins can be detected using a fluorometer.

Aflatoxins can also be detected (but not quantified) using fluorescence under ultraviolet light (figure 12), but keeping in mind that greater fluorescence does not indicate higher aflatoxin concentration. The fluorescence of contaminated samples is not stable and may disappear if the samples have been continually exposed to visible radiation; however, toxin concentration in the sample will remain (Forno et al., 2005).

Figure 12. Maize grain under fluorescent light.

1.4. Moisture

It is important to evaluate the moisture in maize grain to determine grain quality and for commercialization purposes. In general, the cost of maize is determined taking 14% moisture content as a reference. Handling grains with higher moisture content is more costly because the grain must be air- or oven-dried; otherwise, it will deteriorate rapidly. It will also contain fewer solids and therefore yield less dough and fewer tortillas.

The tests most widely used to determine the moisture content of maize grain are carried out using electronic testers that measure the grain's capacity to conduct electricity, or using a near-infrared device (Infratec). The quickest, safest and most economical approach used by collection and research centers is carried out with Steinlite or Motomco meters following the 44-11 method of AACC (2000). The test is run in a matter of seconds on whole grain without destroying the sample; it is based on the principle that bound water and free water within the grain conduct electricity differently.

Direct method

A sample's moisture content is indicated by the weight it loses when exposed to heat, expressed as a percentage of the sample's original weight. The moisture in maize grain is extracted as vapor by applying heat under controlled conditions. The recommended methods were developed to reduce the oxidation, decomposition or loss of other volatile substances, while ensuring that as much water as possible is removed.

This procedure is based on method 44-15 of the AACC (2000), but with a modification: the grain is cut. The method requires using a stove or oven that can reach a constant temperature of 130°C, plus aluminum boxes that hold 2 grams of maize, an analytic balance and a dryer (Figure 13). To determine grain moisture, weigh 2 ± 0.02 g of kernels that have been cut crosswise and place in an aluminum box adjusted to a constant weight. Once the temperature of the oven has stabilized (130 °C), the box containing the sample is placed inside. The sample is exposed to 130 °C for 60 min; the box is then removed from the oven and placed in the dryer to cool, which takes about 10 min.

$$\% \text{ moisture} = \left[\frac{\text{WBWS} - \text{WBDS}}{\text{WS}}\right] * 100 \qquad \text{Eq. (4)}$$

where:

WBWS = weight of the box + wet simple.
WBDS = weight of the box + dry simple.
WS = weight of the simple.

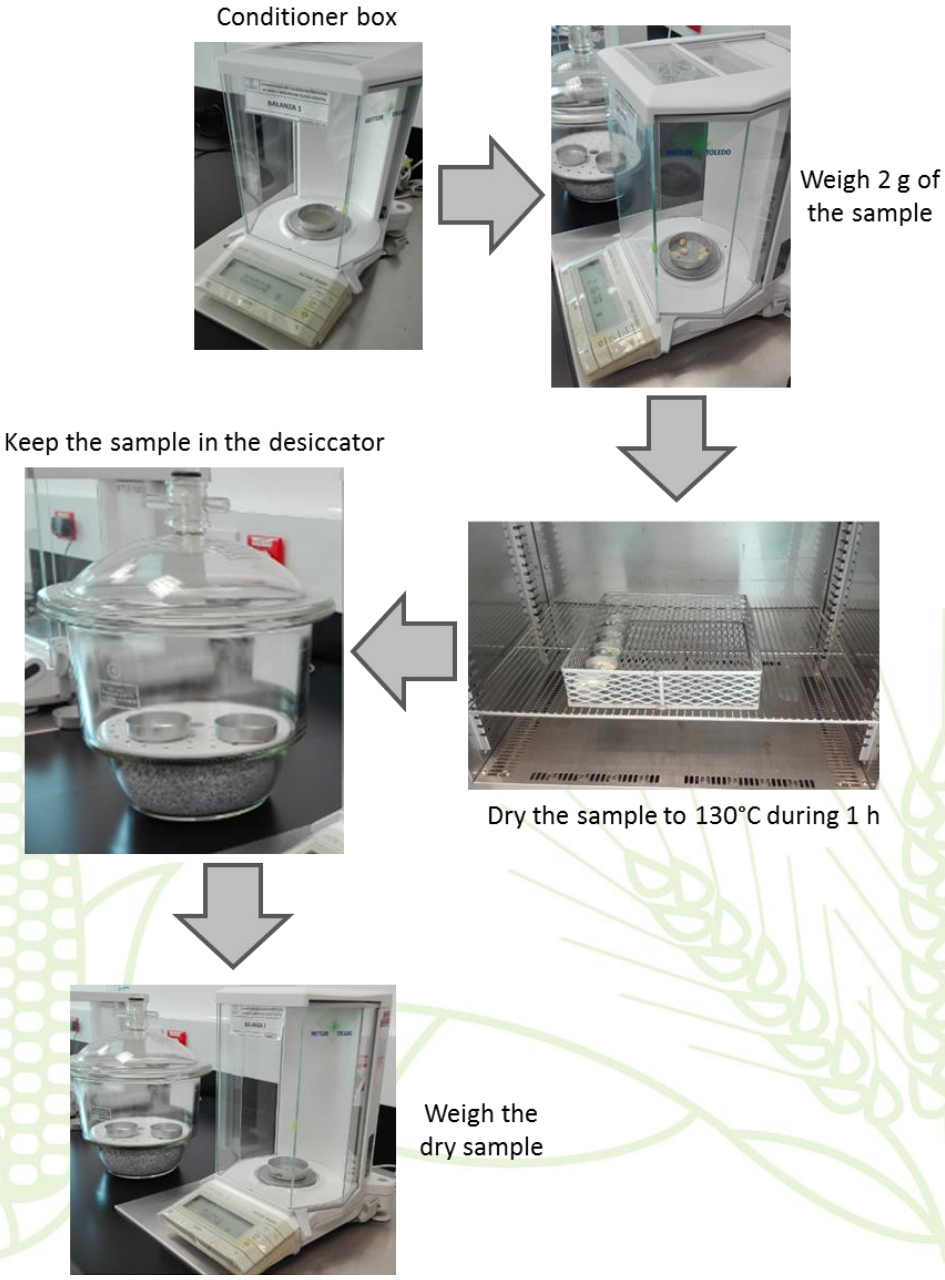

Figure 13. Determining maize grain moisture using the direct method.

1.4.1. Dielectric method

The devices most frequently used by maize storage and processing companies for determining grain moisture are electronic moisture meters. They measure moisture based on electric conductivity (the capacity of maize grain moisture to pass an electric current). The most popular devices are the Motomco and Steinlite meters (Figure 14), but other types of meters can be found on the market. The Motomco and Steinlite meters determine grain moisture on whole kernels in a matter of seconds, without destroying the sample, and they are very easy to operate.

A moisture meter of the Steinlite type must be used with a grain scale. Before measuring grain moisture, the meter is calibrated following the instructions in the users' manual. Weigh 250 g of grain and place in the hopper of the device. Press the button so the sample will be lowered into the reading compartment. After a few seconds, the percent moisture will appear on the meter's screen.

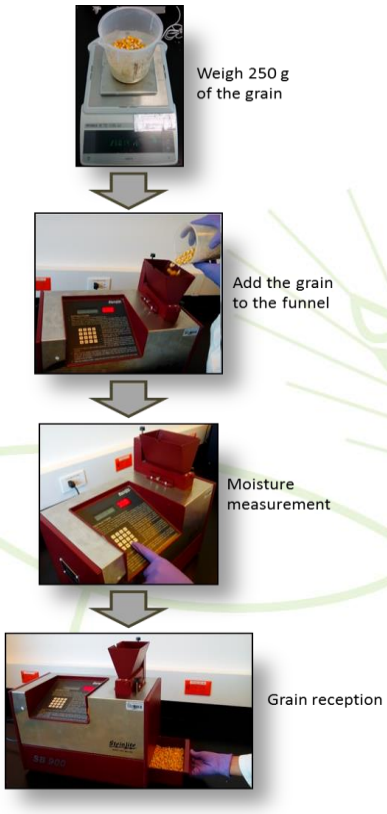

Figure 14. Determining grain moisture with a Steinlite meter using the dielectric method.

II. INTRINSIC QUALITY

2.1. Grain structure

Mature maize grain is the result of an ovule being properly fertilized and receiving the supply of nutrients it needs to grow. Both fertilization and the nutrient supply can be affected by agronomic management (sowing date, fertilization, type of seed used, etc.), biotic factors (pests and diseases) and abiotic factors (temperature, water availability, soil type). However, all maize grains are made up of four essential structures: pericarp or bran (5-6%), endosperm (82-83%), germ or embryo (10-11%) and the tip cap or pedicel (0.8-1.0%) (Singh, Singh and Shevkani, 2011) (Figure 15).

The pericarp is the outermost structure of the grain; it is a thin layer usually about 60-80 µm thick that consists of dense and malleable tissue whose composition is about 77.7% fiber, 9.1% protein, 7.3% starch, 1% fat and 4.4% other substances. All parts of the pericarp are made up of tube-shaped dead cells (Bartolo-Pérez et al., 1999).

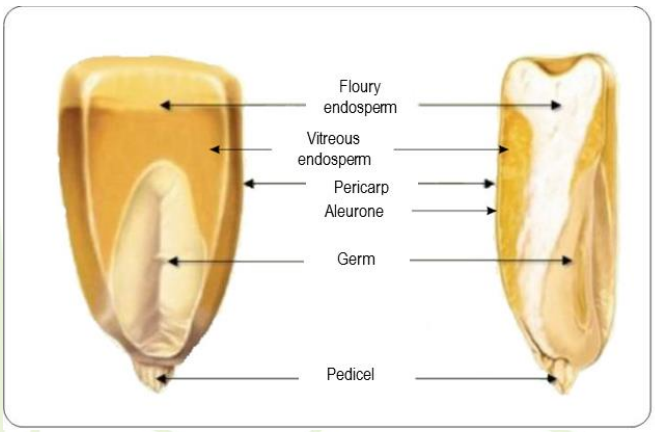

Figure 15. Structure of a maize grain.
Source: http://sevilla.dacsa.com/spa/mundo-maiz/caracteristicas-y-tipos-de-maiz/el-grano-del-maiz.html

The pedicel is the cell structure that joins the grain to the cob. It is made up of vascular bundles that end at the base of the pericarp; it has an outer abscission layer that seals off the end of the mature grain. Next to this layer, a series of star-shaped parenchymal cells come together at the end to form a fragile and porous structure that is connected to the layer of cross cells in the

pericarp. Liquids are absorbed from the pedicel into the pericarp through this structure (Jackson and Shandera, 1995).

The maize germ has high fat (15-30%), protein (10-18%) and mineral salt contents; it stores nutrients and hormones that are mobilized by enzymes synthetized during the initial germination stage (Jackson and Shandera, 1995).

The endosperm is made up of elongated cells that have thin walls of cellulosic material and are packed with starch granules (5-30 μm) in a protein matrix (starch-protein). The structural integrity and bond between the protein and the starch granules contribute to grain hardness. The endosperm consists of two fractions: one floury and one horny. The floury endosperm fraction is characterized by large, nearly round starch granules that are loosely packed together within a thin protein matrix, with many air spaces between them (Mu-forster and Wasserman, 1998). The proportion of these endosperm fractions determines grain hardness; the greater the proportion of floury endosperm, the softer the grain, and vice versa (Watson, 2003). This is also related to the grain's water absorbing capacity, that is, soft maize absorbs more water during the nixtamalization process than hard maize. Flint endosperm has small cells with small starch granules that acquire a polygonal structure and are strongly bound by a protein matrix without air spaces between the granules (INTA, 2006).

The uses of maize are determined mainly by grain structure and composition. The endosperm consists of a floury portion and a flint portion. Grain structure and composition vary depending on the cultivar, as well as on management practices, climate, soil, and harvest and postharvest methods. The maize that is normally used in the nixtamalization process is dent maize.

2.2. Structure quantification (dissection).

The structure of the maize grain that is processed by the nixtamalized flour industry is important because it affects the nixtamalization process and the shelf life of maize flour. The nixtamalized flour industry prefers maize grain having pedicel and pericarp percentages below 2.0 and 5.5%, respectively, because this means the pedicel and pericarp will come off more easily during the nixtamalization process, and will produce flour that is lighter in color (less yellow). The grain's germ percentage should be 12% or less, given that higher amounts increase the oil content, which can clog the hammers during milling; higher amounts of germ will also cause the flour to become rancid after a short time in storage (Vázquez et al., 2003). Proportions of hard endosperm 48% or higher ensure adequate grain hydration, easy milling and facilitate drying of dough particles (Salinas et al., 2012).

The proportion of these structures does not matter to traditional dough and tortilla mills, which use all grain components because they all contribute to the commercial and nutritional quality of tortillas. Traditional millers prefer nixtamalized maize that retains most of its pericarp, because its gum helps produce dough that is cohesive and has good texture (Almeida and Rooney, 1996). However, today it is also common practice to add some nixtamalized flour in order to give the dough better texture.

Maize grain with a high proportion of germ and, therefore, more oil, produces tortillas that have a soft texture, even after they have been reheated (Vázquez et al., 2014). Nixtamalizing maize grain with less than 40% hard endosperm (medium hardness) requires less fuel to hydrate the grain adequately and produces dough and tortilla yields that are slightly higher compared to hard maize grain.

Percentages of the four main grain structures need to be quantified by a highly skilled worker. Quantification also requires a convection oven that reaches 130 °C, an analytic balance, a dental drill with star-shaped bits 1.2 and 3.0 mm in length, an electric grill, a scalpel, a beaker and aluminum boxes.

The quantification procedure consists of randomly selecting 25 grains, weighing them (a) and soaking them for 5 minutes in water at 70 °C. With the help of a scalpel, separate each grain component (pedicel, pericarp, germ and endosperm) and place them in the aluminum boxes at a constant weight. Record the dry weight of each component (j, k, L). Take 5 of the 25 endosperms, weigh them, and record the weight (b). Quantify the moisture of the remaining 20 endosperms; heat them at 130 °C for one hour. Remove from the oven and cool them in a dryer. Once they are cool, weigh them and calculate the moisture (Equation 4).

Remove the floury portion of the five endosperms with a drill (Figure 16). If you do not have a drill, use a scalpel. This part of the process requires a highly skilled worker to remove only the floury portion. Record the total wet weight of the hard portion that was left whole (c); determine and record grain moisture (H2) following the procedure described above. These calculations are described in Equations 5-10.

$$m = \left[a - \frac{H1}{100} * a\right] + j + k + L \qquad \text{Eq. (5)}$$

$$\%\ \text{Pedicel} = \left[\frac{j}{m} * 100\right] \qquad \text{Eq. (6)}$$

$$\% \text{ Pericarp} = \left[\frac{k}{m} * 100\right] \quad \text{Eq. (7)}$$

$$\% \text{ Germ} = \left[\frac{L}{m} * 100\right] \quad \text{Eq. (8)}$$

$$\% \text{ Floury endosperm} = \left[\frac{\left[\left(\frac{H1}{100 * b}\right) - \left(\frac{H2}{100 * c}\right)\right]}{\left(\frac{H1}{100 * b}\right)}\right] * 100 \quad \text{Eq. (9)}$$

$$\% \text{ Hard endosperm } = 100 - (\%\text{Pedicel} + \%\text{Pericarp} + \%\text{Germ} + \%\text{EH}) \quad \text{Eq. (10)}$$

$$H1 = \left[\frac{[(d - e)]}{d}\right] * 100 \quad \text{Eq. (11)}$$

$$H2 = \left[\frac{[(b - f)]}{b}\right] * 100 \quad \text{Eq. (12)}$$

where:

m = amount of solids in the grain
a = weight of 25 endosperms
b = weight of 5 endosperms
c = wet weight of the hard endosperm
j = dry weight of the pedicel of the 25 grains
k = dry weight of the pericarp of the 25 grains
L = dry weight of the germ of the 25 grains
H1 = moisture content of the 20 endosperms
H2 = moisture content of the hard endosperm
EH = floury endosperm
d= weight of 20 wet endosperms
e= weight of 20 dry endosperms
f= weight of 5 dry endosperms

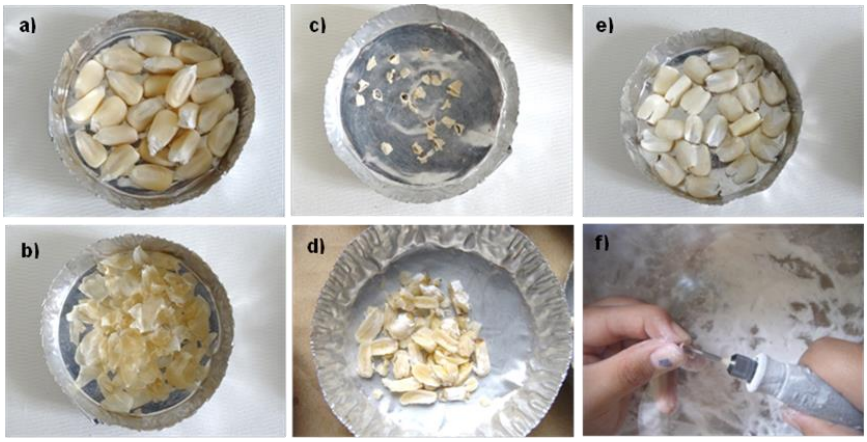

Figure 16. Grain dissection: a) Whole grain; b) Pericarp; c) Pedicel; d) Germ; e) Endosperm; f) Separating the floury and hard endosperm.

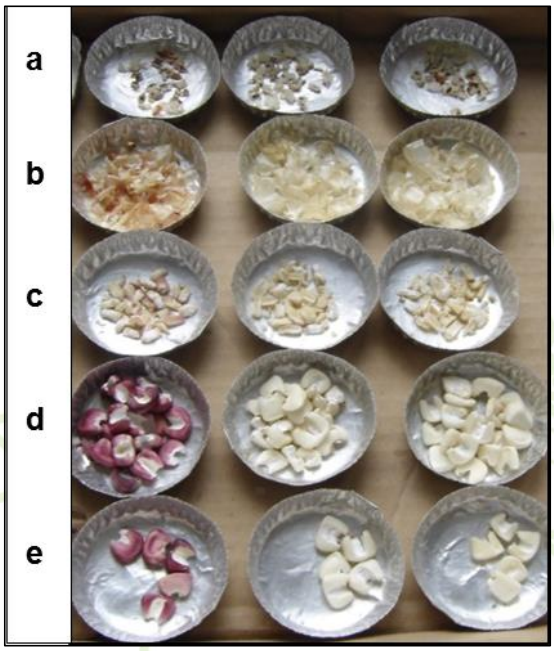

Figure 17. Differences in grain structure: a) Pedicel; b) Pericarp; c) Germ; d) Whole endosperm; e) Hard endosperm.

2.3. Classifying grain by shape and size.

Maize grains have different shapes and sizes, depending on their position on the cob, the genetics of the plant they come from, and the environmental conditions where they developed. Grains at the base of the cob are usually big and round, the ones on the top end are small and round, while the ones in the predominant middle part may be flat. The nixtamalization industry prefers medium-sized dent grains (Figure 18) because they can be hydrated in a reasonably short period of time.

Grain size is important for the nixtamalization process because if grains of different sizes are processed, you run the risk of producing dough that does not roll out adequately, resulting in poor tortilla texture.

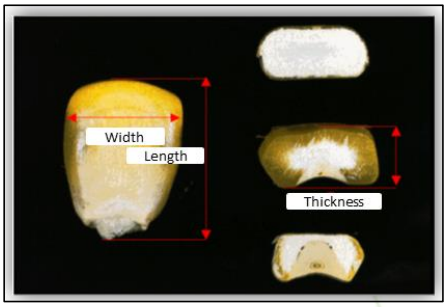

Figure 18. Front and crosswise views of a maize grain.

Today, maize processing companies have better quality control and use gravity tables to classify and separate healthy grain from damaged grain, and remove impurities as well as malformed, immature or broken kernels. Gravity tables are also used to separate large grains from small grains, and hard grains from soft grains. All this is possible thanks to an air system driven by fans located on the lower inside part of the machine and to the oscillation in the upper part (cover) of the machine. This procedure produces uniform raw material ideal for optimum processing. At the experimental level, metal sieves with round holes are manually or mechanically shaken to separate impurities, foreign matter, broken kernels, etc. Lots made up of grains of uniform size are retained on the different sieves. Grain homogeneity is determined by quantifying the percentages of grain remaining on No. 3 and 4 sieves with holes 0.686 and 0.477 in diameter.

A grain scale with 0.5 precision and a set of sieves with metal screens with round holes are needed to determine grain size (Figure 19).

The procedure consists of putting the sieves in order by placing the one with the largest holes (0.95 cm) on top, followed (downward) by the one with medium-sized holes (0.793 cm) and then the one with the smallest holes (0.635 cm). Finally, a sieve with a closed bottom (called a tray) is placed at the bottom of the pile.

Take a 1-kg sample from the clean sample with 12-14% moisture content. Pass the sample through the sieves by shaking for one minute. Weigh the grain remaining in each sieve. Record the weight, divide it by 10 and note down the percentage of grain retained in each sieve.

Figure 19. Classifying maize grain size using sieves.

2.4. Measuring grain size using a vernier scale or micrometer.

A vernier scale is an instrument for taking direct measurements that produces precise measurements, starting from 0.001 inches or 0.02 mm, depending on the metric system used to calibrate it (Krar et al., 2003). A vernier scale is easy to find and using it does not require specific skills. It is recommended for classifying grain into different sizes, because it measures length, width and thickness (figure 20). Measurement precision depends on correctly taking a random sample of 10 grains on which to take the three measurements. At the end, calculate the average and standard deviation, and estimate which sieve will retain them. The lower the standard deviation, the more homogeneous the grain. Doing this type of analysis is recommended when the amount of available grain is limited or when other devices or meters for performing this classification are lacking.

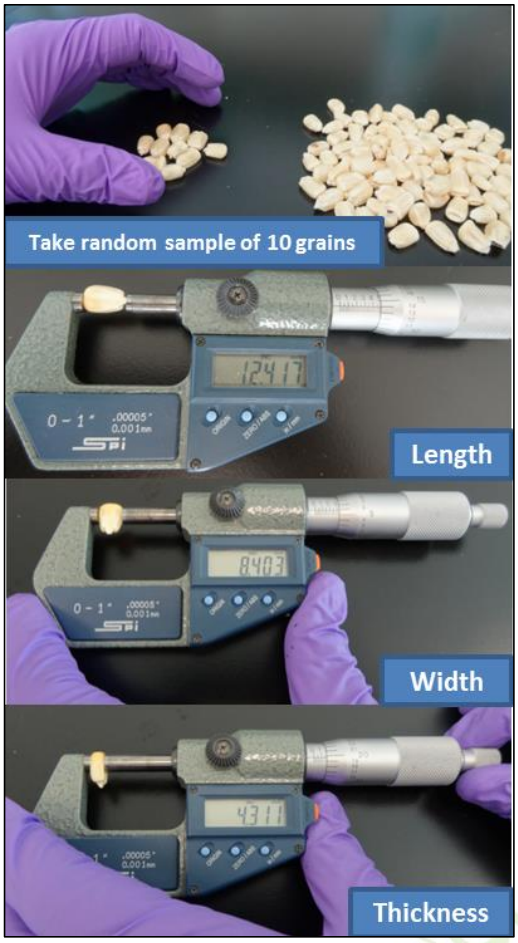

Figure 20. Measuring the length, width and thickness of each grain.

2.5. One thousand-grain weight

One thousand-grain weight is an indirect measurement of grain size (Billeb and Bressani, 2001). This test is important because grain size is related mainly to dough and tortilla yields. The dough-tortilla and nixtamalized flour industries prefer grains of uniform size for uniform cooking. This test is simple, practical and quick.

To do the test, select 100 clean whole grains at random. For convenience, select them from the sieve that retained the highest percentage of grain after performing the grain size homogenization (2.3) test. Note down the weight and multiply by 10. Do the test twice. The only requirement is a scale with two decimal precision. Classify the grain size according to the classification in Table 4.

Table 4. Classifying maize grain size based on 1000-grain weight.

1000-grain weight (g)	Size classification
> 380	Large
330 – 380	Medium
< 330	Small

Source: Salinas and Vázquez (2006).

2.6. Density

2.6.1. Test weight (bulk density)

Test weight is the criterion most frequently used to determine the bulk density of maize grain. It is quantified by weighing a sample (1 liter of grain) representative of the grain lot. It is generally expressed in kg hL-1 (100 liters). Test weight is associated with the grain's actual bulk density and, therefore, with the texture (hardness) of the endosperm and its health. Grains that have been damaged by insects have lower test weight values than healthy grains, while grains with hard endosperm have higher bulk density. Grain lots with higher kernel moisture have lower test weight (Serna, 1996).

Seed shape and size are important when determining test weight because they influence the way the grains settle in the test container. Another important factor is the intrinsic density, which depends on the grain's physical structure and chemical composition, in addition to its moisture (Pomeranz et al., 1986).

Two scales are needed to do the test, one to weigh the grain (maximum capacity: 1 kilogram) and a test weight scale, which consists of a fixed support with a hopper and an integrated scale, a metal 1-L container and a weighted and balanced metal handle, a small wooden ruler with rounded edges and a tray with a funnel at the end (Figure 21).

This methodology (method 84-10) was described and validated by AACC (2000). It can be used on the original sample (with impurities, high grain moisture, damaged grains, etc.) or on a clean

sample of known grain moisture. We suggest using the kilo of maize grain that was previously separated in the sieves to quantify the impurities (Section 1.1).

The first step is to adjust the scale to zero by taking the tare weight with an empty 1-L container. Then place under the bin and verify that the bin's trap door valve is closed. Add the maize grain to the bin and open the trap door making sure the grain falls freely into the middle of the container until it is filled to overflowing. Remove the grain overflow by scraping with a ruler using three zig-zag motions starting at the edge of the container, without pressing down on the sample. Weigh the container with the grain on the integrated scale and note down the weight per unit volume expressed in kg hL-1.

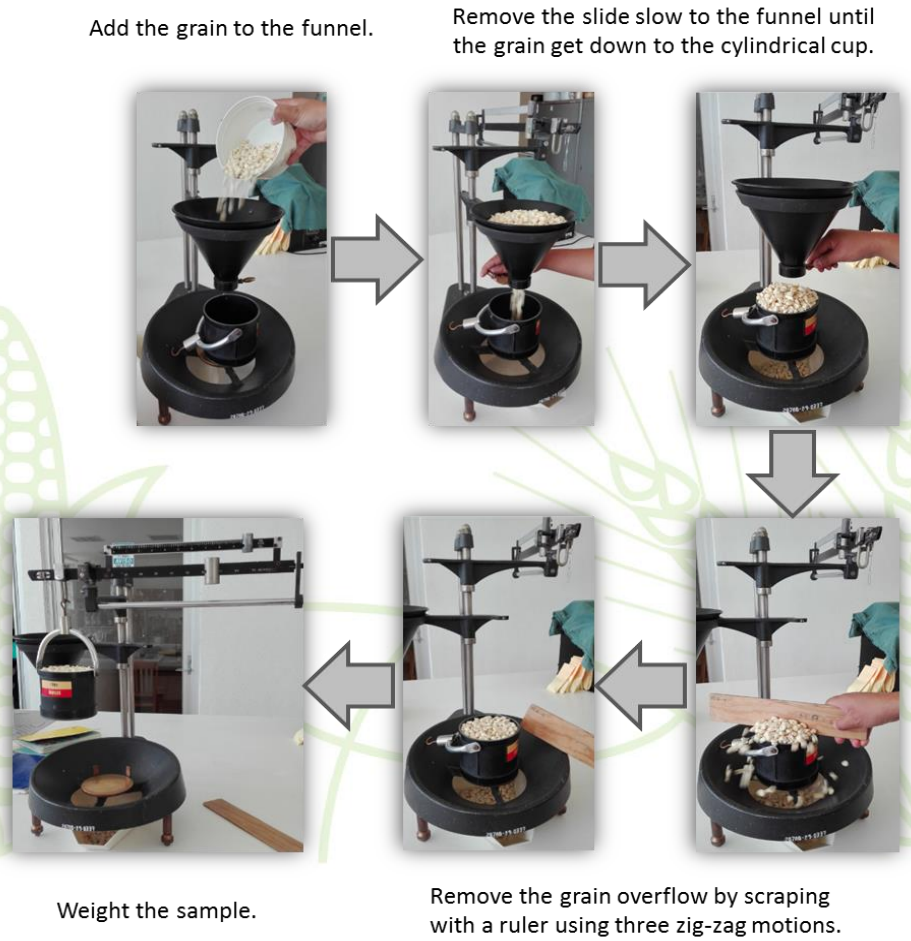

Figure 21. Determining test weight.

According to Mexican norm NMX-FF-034/1-SCFI-2002, white maize grain that will be used to make tortillas should have a test weight equal to or higher than 74 kg hL-1. According to Salinas and Aguilar (2010), this value indicates medium hardness (Table 4).

Table 5. Classifying maize grain hardness based on test weight.

Test weight (kg hL-1)	Hardness
78	Hard
74 - 75	Medium
73	Soft

Source: Salinas and Aguilar (2010).

2.6.2. An alternative method for determining the bulk density of maize grain

If you do not have a test weight scale, we suggest doing this in a similar way, but using a scale, a round 1-L container 10 ± 0.5 cm high and an inner diameter of 11 ± 0.5 cm, with a flat bottom and a support where a funnel-shaped hopper can be screwed on; around the neck of the funnel is a release key which when open allows the grain to fall from the same height during all the tests. A 30-cm school ruler can be used to remove excess grain from the container.

Under this scheme, the result obtained is the weight in grams (g) of a liter of maize grain. To convert this into the value given by the scale, divide by 10; the values should be the same.

A strong association or significant correlation (R2 = 0.94) between the two procedures was observed when comparing the value obtained using the test weight scale and the weight of a liter of the same maize kernels.

2.6.3. Hardness

Maize grain hardness is defined as the force needed to break the grain; it helps give the grain mechanical resistance, which is desirable for maintaining the grain whole during harvest and postharvest operations. However, this parameter also determines the grain's capacity to absorb and retain water during the different stages of the cooking process, especially during nixtamalization and steeping process. So-called soft maize hydrates more rapidly than hard maize and also absorbs more water because it's easier for the water to reach its starch granules (Watson, 2003; Salinas and Aguilar, 2010).

Maize endosperm hardness is perhaps the most important characteristic, not only for dry milling, but also for wet milling. It is also crucial for the grain's durability during storage and transport, as well as for its commercialization.

Different methods for determining grain hardness have been developed to help the maize industry improve maize processing efficiency and inform farmers of the quality specifications that consumers demand (Blandino et al., 2010). Two important factors that contribute to greater exactness and precision when determining grain hardness are grain moisture (given that the higher the moisture, the softer the endosperm) and the homogeneity of the sample (the greater its heterogeneity, the lower the precision).

Methods for measuring grain hardness include measuring its grinding resistance, abrasion, grits production and starch gelatinization properties, milling followed by sieving and determining the number of particles that pass through the mesh of the sieves. Near-infrared reflectance and transmittance have also been used. The units and intervals used for soft and hard grains vary depending on the method used (Fox and Manley, 2009). However, there are significant correlations between results obtained by some of these methods; for this reason, the specific method used depends on the availability of the equipment, the speed with which the result has to be produced and the data's end-use (breeding, industrial, research).

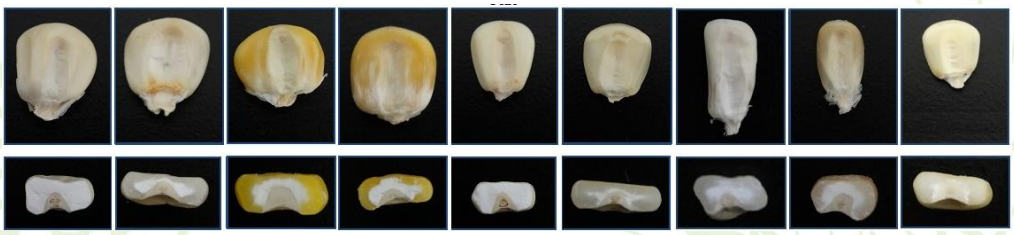

Figure 22. Floury endosperm/hard endosperm ratio. Front and crosswise views of different maize grains.

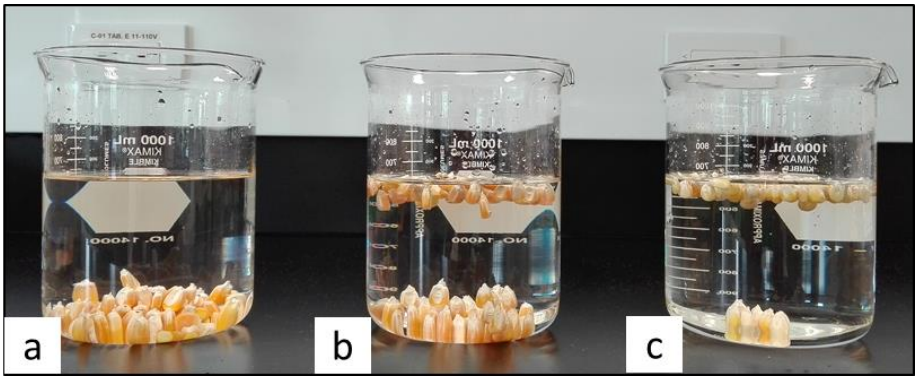

Figure 23. Flotation index: a) Very hard grains; b) Medium-hard grains; c) Very soft grains.

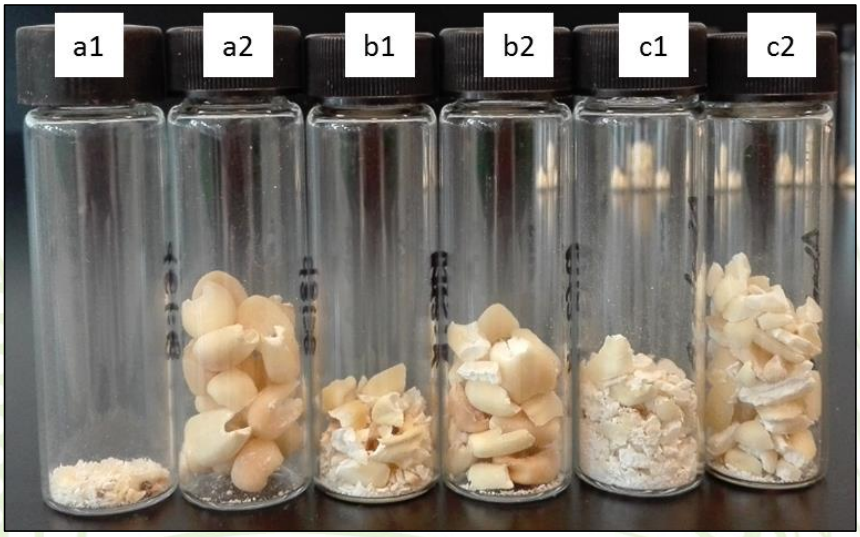

Figure 24. Vitreousness. Samples a1, b1, c1: floury endosperm. Samples a2, b2, c2: hard endosperm.

The nixtamalized flour industry uses hard or very hard grain as a raw material in order to produce fractions of adequate size for the different applications. The tortilla industry needs to know this parameter in order to cook the maize for the correct time during nixtamalization and prefers medium-hard and hard grains (Robutti et al. 2000; Salinas and Aguilar, 2010).

2.6.3.1. Flotation index (sodium nitrate)

The flotation index is based on the number of grains that float in a reference solution; this depends on the density of the grain vs the density of the sodium nitrate or sugar solution; thus the harder the grain, the lower its flotation index value. Since the percent moisture of a sample greatly influences the result, the recommendation is that the test samples should all have the same percent moisture (about 12%) (Salinas and Vázquez, 2006).

An analytic balance, a pycnometer, a stove with controlled temperature, a sieve and several glass 500-mL beakers are needed to measure the flotation index.

To prepare a sodium nitrate solution with a density of 1.2500 g mL-1, add 41 g of sodium nitrate per 100 mL of distilled water to a beaker. After shaking vigorously, measure the density (which may vary depending on the purity of the reagent) with the help of a hydrometer (a pycnometer for liquids). The hydrometer should be kept at a constant weight and handled with gloves to avoid adding oil from the hands.

Weigh the hydrometer using an analytic balance and record it as P1. Fill the hydrometer with distilled water and weigh (P2). Rinse the hydrometer and dry with a paper towel. Fill the hydrometer with the nitrate solution and weigh (P3). Calculate the density following equation 11.

$$\text{Density} = \frac{P_3 - P_1}{P_2 - P_1} \qquad \text{Eq. (11)}$$

If the density is higher than 1.2500 gmL-1, add a few drops of water and repeat the previous steps to calculate the density again. If the density is lower than 1.2500 gmL-1, add a few grams of sodium nitrate. Repeat the same operation until the required density is reached with a ±0.0005 margin of error.

Determining the flotation index requires randomly selecting and counting 100 whole and healthy maize grains. Place them in 500 mL of the sodium nitrate solution and mix them with a glass stirring rod or a spatula. Wait one minute until they stabilize (Figure 25). Count the grains that rise to the surface or float and record the reading as a percentage.

Figure 25. Determining the flotation index.

2.6.3.2. Alternative methods for classifying maize grain hardness

Besides sodium nitrate, other more easily available solvents have been tried that fulfill the methodology's objective of distinguishing maize grains based on their density.

One of the objectives is that this type of methodology should be easily used by the different actors in the maize chain. Different inexpensive and easily available solvents, such as sugar, salt and lime, have been evaluated recently as replacements for sodium nitrate. Of the three, the sugar solution was the one that worked best, for it showed a 0.99 correlation with sodium nitrate; it is also water soluble, easy to obtain and reaches the density required for this test.

a) Refined sugar as a solvent

Sugar is commonly eaten and thus readily available. Using sugar as a solvent requires very few instruments if the suggested materials are used, the recommendations are followed (Table 6) and the procedure described is performed. Results are 99% reliable and comparable to the results obtained with sodium nitrate. To perform this test, you need a balance with 1-g precision, 2 transparent glass or plastic 1-L beakers on which volumes of 580 mL and 1 L are indicated, a clean container with no cracks for weighing, paper towels, two plastic spoons and a sieve.

Table 6. Preparation of reagents used to determine the flotation index using sugar.

Reagent/Mixture	Specific reagents/ Specifications	Preparation	Special recommendations
67% sugar solution, with 1.25 g mL-1 density	Refined sugar	See instructions in the procedure.	Prepare the solution each time you use it; do not store for more than three days A 500-mL volume is enough to determine the flotation index of 20 maize samples in replicate
Purified water	A 1.5 L bottle water, with mark of 1 L.	Use immediately	Must be kept at room temperature (about 25 °C).

To prepare a 67% sugar solution, weigh 670 g of refined sugar and add it into the 1.5 L bottle with the mark of 1 L the water, add the water slowly until fill de water to the 1 L mark, mix constantly. Avoid spilling or splashing water. Once the sugar is dissolved, the total volume of the resulting solution should be exactly 1 L.

To determine the flotation index (FI) (that is, the number of floating grains), select 100 whole and healthy grains (take them from the sieve that retained the highest number of kernels after quantifying impurities) and record their weight (100-grain weight). Add 500 mL of the sugar solution to a 1-L transparent glass beaker. Add the 100 grains to the solution and stir three times to the right and three times to the left with a spoon. Let rest for 30 seconds so the grains will float or sink to the bottom. Remove the floating grains with a spoon, put them in a sieve and quantify. Do at least two evaluations per sample. Classify hardness according to Table 7.

Table 7. Classification of maize grain hardness based on its flotation index.

Floating grains	Hardness
0-12	Very hard
13-37	Hard
38-62	Medium
63-87	Soft

88-100	Very soft

Source: NMX-FF-034/1-SCFI-2002.

2.8. Color determination

The color of maize grain varies depending on where it comes from, its germplasm source, management, etc. It definitely influences the preferences of industry and consumers. It is also considered a quality control measure of the final products. Determining color using instruments is simple, objective, precise and quick.

Color is important because it usually determines consumer preferences. People in Mexico, in particular, usually prefer white maize above all other types, which tends to increase its price.

2.8.1. Agtron colorimeter

The nixtamalized flour industry uses an Agtron colorimeter (Figure 26) to measure the color of the maize it processes and the flours it produces. It is a monochromatic light colorimeter that measures in relative units the amount of light that is reflected in the red, green, blue or yellow regions following the 14-30 method (AACC, 2000), which indicates that the color of cereals should be measured on wet flour (35% moisture) to accent and intensify its color; the device should operate in green mode (546 nm) because that is the best color for comparing the products' apparent color.

To obtain comparable values, the colorimeter must be calibrated according to the product to be evaluated. The sample is placed in the container of the colorimeter and the readings are made. The recommendation is to fill the capsule with grain, nixtamal or dough, and scrape to level. The color of tortillas is measured by cutting out a tortilla round of the same size as the capsule's diameter. The results are expressed as percent reflectance.

Figure 26. Agtron colorimeter.

2.8.2. HunterLab colorimeters

The colorimeters most often used to measure color are the Hunter Lab spectrophotometer and the Agtron colorimeter. The Hunter Lab device is a spectrophotometer that can measure true colors in a manner similar to how they are perceived by the human eye. It registers the intensity of the light that is absorbed by the color black or reflected by the color white, as well as the light that decomposes into the primary colors (red, blue, yellow) and mixtures thereof: purple, green and orange. Color values are read directly using three scales: L*, a* and b*. This is the CIELab scale; the first three letters are the French acronym for the International Illumination Commission (Commission Internationale de L 'Eclairage); the last three letters are the Hunter Lab scales.

The Hunter Lab spectrophotometer consists of a three-dimensional coordinate system. The "L" scale measures luminosity (reflected luminosity or light-reflecting capacity) and ranges from 0 (for black) to 100 (for perfect white). The "a" scale measures the color red on the positive side (+a) and the color green on the negative side (-a). The "b" scale measures the color yellow on the positive side (+b) and blue on the negative side (-b). Both scales (a and b) detect the color gray when the reading is 0.

Before using the Hunter Lab colorimeter, select the scale you will use. In this case, adjust it using the CIELab scale according to the L*, a*, b* values of the white and black mosaics included in the colorimeter. The readings are done in the Daylight mode with a D65/10° color angle.

Place the sample in the container of the colorimeter; push the read button and the L*, a* and b* values will appear. These values can be transformed and expressed in quantitatively definable dimensions such as "hue" and "chrome" or "color purity", in addition to luminosity. The first variables are calculated using Equations (12) and (13).

$$\text{Hue} = \tan - 1\ [\text{b} * / \text{a} *] \qquad \text{Eq, (12)}$$

$$\text{Chrome} = \sqrt{\text{a} * 2 + \text{b} * 2} \qquad \text{Eq. (13)}$$

Hue values are expressed in degrees (°) or radians; chrome values are adimensional, as can be seen in the equation. Negative a* or b* values make the hue values become negative as well; to

express them in positive terms, correct them by subtracting the negative value from the supplementary angle.

Is nixtamalization an alternative to reduce mycotoxin consumption from maize-derived food?

Mycotoxins are fungal secondary metabolites that contaminate 25% of agricultural crops worldwide, also their derivate and threaten human health (Smith et al., 1994). Contamination of food supplies by these and other naturally occurring toxins is of particular concern in rural communities of developing countries (Bhat et al., 1997).

The most common mycotxin found in maize are aflatoxins produced by Aspergillius flavus y Aspergillius parasíticus; and fumonisins produced by Fusarium verticillioides and F. proliferatum **(Torres et al., 2008).** Food processing could contribute to reduce the levels of mycotoxins. Selection of raw material, washing, milling, cleaning, dehulling, toasting, baking, frying, lime-cooking could contribute to their reduction.

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De-hulling can reduce up to 92% of the aflatoxin content (Siwela et a., 2005). Fumonisins are highly tolerant to heat, but they are degraded by baking, extrusion, roasting and lime-cooking (Dall'Asta et al., 2008). Lime-cooking can reduce in 50 to 80% the fumonisins by hydrolysis of Fumonisin B. Higher concentration of lime leads to lower content of fumonisins in nixtamalized dough and tortillas (De la Campa, Miller & Hendricks, 2004). Most of the fumosins are found in the cooking liquor (nejayote).

Aflatoxins have high decomposition temperatures in a range of 237 °C (AFG2) to 320 °C (AFP1). AFB1 in crystals is very stable to dry heat up to 267 °C. The domestic boiling temperatures reach around 150 °C, so AFB1 and AFG1 are not destroyed. Nevertheless, the reduction of these toxins will depend on the initial level of contamination, temperature and heating time as well as the type of AF and the food (Rustom, 1997).

In alkaline solutions the hydrolysis becomes slow in the lactone ring of the AFs. This hydrolysis is reversible, with the formation of the environmental acid ring (Price and Jorgensen, 1985; Moctezuma et al., 2015).

The role that pH plays in the AF inactivation happens at temperatures higher than 100 °C. The effects of pH (5, 8 and 10.2), with temperatures (121, 130 and 140 °C) and heating times (from 5 to 20 seconds and 15 minutes) over the mutagenic activity of peanut beverages artificially

contaminated with AFB1 were reported (Rustom, 1993). The treatment with pH 8.0, had no effect on AFB1 mutagenicity, but additional treatments from pH 10.2 to 130 °C, for 20 seconds, and from pH 10.2 to 121 °C, for 15 minutes reduce AF up to 78 and 88% respectively. The lactone ring hydrolyzed by the NaOH added to adjust the pH. The treatments done from pH 5 to 130 °C, for 20 seconds, diminished the mutagenicity in 76 % and with pH 5 at 121 °C for 15 min diminished in 73 %. The reduction of the mutagenic effect was attributed to the partial lactone ring hydration in the presence of HCl added to adjust the pH. AFB1 is transformed to AFB2a that is 1000 times less mutagenic.

Moctezuma et al., (2015) recently showed that the alkalinity of the lime treatment (pH 12.0) and the acidity of gastric fluid (pH 1.2) inhibited AFB1 mutagenicity. However, the neutral pH of saliva (pH 7.0) increased mutagenicity, and of pancreatic fluid returned the mutagenicity to untreated levels. The mixture of saliva with gastric and pancreatic fluids (pH 5.8) that is the situation present in the colon also rendered the AFB1 mutagenic (Moctezuma et al., 2015).

As can be appreciated the points of fusion of AFs are very high so they resist boiling temperatures of foods, milk pasteurization, ultrapasteurization and alcoholic fermentation of beers without breaking. Lime treatment (“nixtamalización”) only disguise them, it doesn´t eliminate them. Further detailed studies will be necessary to elucidate the controversy. However, what is clear until now is that the maize is not highly contaminated with aflatoxins, lime-cooking will contribute to a decrease of them by the elimination of the pericarp, as it does the de-hulling.

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Anexo 1. Nixtamal millers and maize tortilla machines.

Model	Proveedor	Description	Power
Tortilla presses. 	Máquinas González.	Diameter: 8” Stainless steel.	
Electrical tortilladora with strip TEB-G. 	Máquinas González.	Machine packed dimension: 0.41 X 0.7 X 0.35m. Include: Head, Hopper, cutter, strip, motor.	90 W. 120 V. 60 Hz.
Manual head with plastic rollers.	Manufacturas LENIN.	Machine packed dimension: 1.3X 0.8 X 0.9 m.	Does not need a motor for work.

			
Corn tortilla machine ML-30. 	Manufacturas LENIN.	Machine packed dimension: 1.56 X 2.3 x 0.7 m. Capacity: 960 kg / h.	
San Luis Mill 	Manufacturas LENIN.	Machine packed dimensions: 1.1X 0.9 X 0.6 m, 1.3 X 1.5 X 0.9 m and 1.55X1.5 X 0.9 m. Stones:5 – 9” Capacity: 60 to 250 kg / h.	Motor 1 hp to 7.5 hp.
Molino baby	PEGASO	Machine packed dimension: 0.92 X 0.86 X 0.49 m. Stainless Steel. Stones: 6” Capacity: 80 Kg / h.	Motor 3 hp.

			
Automatic miller. 	La casa del molinero.	Machine packed dimension: 1.2 X 0.96 X 1.6 m. Stainless Steel. Stones: 10” Capacity: 350 kg / h.	Motor 5 hp.