Chapter 9 Evaluation of an alternative nixtamalization method in maize landraces from Chiapas

Capítulo 9 Evaluación de un método alternativo de nixtamalización en maices criollos de Chiapas

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Abstract

In the State of Chiapas, México there is a great diversity of maize landraces (*Zea mays L.*) among which there are pigmented grain variants that have been little used in nixtamalization. The objective of this research was to evaluate an alternative cold method using four different creole genotypes corn (white, yellow, red and purple) in order to propose a process alternative focused on reducing the process time and having similar product characteristics to traditional nixtamalization. A pre-treatment was used in the corn with an excess of water with calcium hydroxide (2%) at room temperature called "Cold Nixtamalization". Different treatments were evaluated with soaking times before cooking (8, 10 and 12 h) and repose time in the nejayote water (6, 8 and 12 h). The variables studied were dry grain moisture, wet grain (nixtamal) and dough, coccion time, pH of the nejayote and dough yield. The best treatment to reduce the coccion time was 12 h of soaking up at room temperature before coccion and 8 h of repose, which caused a decrease in the consumption of gas or firewood, the physicochemical characteristics of dough and tortillas were obtained similar to that of traditional nixtmalization, as well as in pH conditions, process performance.

Pigmented corn, Physicochemical characteristics, Time and process performance

Resumen

En el Estado de Chiapas, México existe una gran diversidad de variedades criollas de maíz (*Zea mays L.*) entre las que se encuentran variantes de grano pigmentado que han sido poco utilizadas en la nixtamalización. El objetivo de esta investigación fue evaluar un método alternativo en frío utilizando cuatro diferentes genotipos de maíz criollo (blanco, amarillo, rojo y morado) para proponer una alternativa de proceso enfocada a reducir el tiempo del mismo y que tenga características de producto similares a la nixtamalización tradicional. Se utilizó un pretratamiento en el maíz con un exceso de agua con hidróxido de calcio (2%) a temperatura ambiente denominado "Nixtamalización en frío". Se evaluaron diferentes tratamientos con tiempos de remojo antes de la cocción (8, 10 y 12 h) y tiempo de reposo en el agua de nejayote (6, 8 y 12 h). Las variables estudiadas fueron humedad del grano seco, grano húmedo (nixtamal) y masa, tiempo de cocción, pH del nejayote y rendimiento de la masa. El mejor tratamiento para reducir el tiempo de cocción fue 12 h de remojo a temperatura ambiente antes de la cocción y 8 h de reposo, lo que provocó una disminución en el consumo de gas o leña, se obtuvieron características fisicoquímicas de la masa y de las tortillas similares a las de la nixtmalización tradicional, así como en las condiciones de pH, rendimiento del proceso.

Maíz pigmentado, Características fisicoquímicas, Tiempo y rendimiento del proceso

1 Introduction

From a food point of view, corn is one of the most important crops in Mexico because the national consumption of corn has registered a sustained growth since 2012. For the years 2019/2020, a record domestic consumption of 44.5 mdt was projected, almost 400 thousand tons above the consumption of the immediately previous cycle. (FIRA, 2020). In Mexico and some Central American countries, corn is consumed mainly in the form of a tortilla, a food that is obtained through out a very old process called "Nixtamalization" (FAO, 1993). However, it is well known that the process has several variants, among which the excessive use of water, energy inefficiency, and long process times, among others.

Currently, it has not been possible to develop a technology that completely replaces the traditional nixtamalization process, since the results obtained in the dough and tortillas do not meet the physicochemical and rheological characteristics required by consumers. Therefore, a new alternative process must be generated that allows the improvement and optimization of the traditional process without affecting the final quality characteristics of the processed products. It is also important that these process alternatives are used in natives corns to give added value to what the region produces.

A pre-treatment of corn genotypes from the State of Chiapas, Mexico (white, yellow, red and purple) was evaluated before starting the traditional nixtamalization process, it consisted of exposing the corn to an excess of water with lime at room called "Cold Nixtamalization", in order to increase cohesion, improve water absorption and therefore reduce coccion times and process costs.

Tests were carried out on the final product (dough and tortillas), process performance, and pH evaluation of the nejayote under the norms that regulate the consumption of nixtamalized corn foods, in addition to its comparison with the traditional nixtamalization process.

2 Theoretical framework

Corn is the most important crop in Mexico and is essential in the diet of Mexicans, it is present in the production of more than 4 thousand products (starch, fructose, oils, cardboard, chocolates, biofuels, animal feed); It occupies little more than half of the sown area of the country and unlike other cereals, it can be grown in almost all climates, almost all altitudes and all soils. It grows early, it is easy to store and to keep for a long time; It is prepared with simplicity and does not require complex equipment to consume it. (Fuentes, 2012).

Mexico is considered as the center of origin and diversity of corn, which has led farmers to apply many of the practices taught by their ancestors, in addition to conserving native materials, the knowledge and practices that reflect a great evolution among crops and human populations.

During 2009 and 2010, maize collections of landraces werw collected in Chiapas, Mexico with subsistence farmers and collected 700 varieties finding a wide diversity of races (18) and grain color (8), most of them are used in the Nixtamalization process. (Coutiño *et al*., 2015). There are currently 59 unique Mexican landraces varieties registered.

Sierra-Macías *et al*., (2014) classified the varieties in the following groups:

Conical Group or races from the highlands of central Mexico: those whose outstanding characteristic is the pyramidal shape of their ears; they are predominantly distributed in regions with elevations of more than 2,000 m mainly and the races of this group are: Arrocillo, Cacahuacintle, Conic, Conical corn, Chalqueño and Mushito.

Group of eight-row corn or races of western Mexico: includes those that are cultivated at low and intermediate elevations, from the central valleys of Oaxaca to the glens of northwest Mexico (CONABIO, 2011; Sánchez *et al*., 2000), It is grown especially for consumption as corn and for various special uses (cookies, pozole, huachales, tejuino, etc.), the main races are Onaveño and Bolita.

Precocious or early maturing tropical maize races: they are grown mainly in the dry tropics and semi-arid regions of the country (100-1300 m), adapted to limited humidity regimes that have given them a short or early maturation cycle. The Raton race is the main one of this group and has been widely used as a material in the development of improved materials. (Sierra - Macías *et al*., 2018).

Group of tropical toothed maize: they are agronomically very important races of southern Mexico, distributed mainly in intermediate and low-altitude regions. These and their hybrids are probably the most used in genetic improvement programs worldwide, the races considered in this group are: Tuxpeño, Tepecintle, Vandeño, Celaña, Pepitilla and Nal-Tel de Altura (Sánchez *et al*., 2000).

Group of late maturing maize: includes races that are grown in wide areas at different altitudes (Aragón *et al*., 2006). Their range of adaptation has facilitated the cultivation of some of them from sea level to high hillsides, a humidity and cloudy condition in the southeastern mountains and center-east of the country (Ortega, 2003; CONABIO, 2011). The races mainly considered in this group are Olotillo and Coscomatepec.

The Olotón race dominates in the upper parts of the southeast of the country, generally above 1,900 m, in the state of Chiapas, it is typical of the Altos, Selva and Soconusco regions, it has also been collected in Oaxaca (Aragón *et al*., 2006, CONABIO 2011); and it extends to Guatemala, where it presents a great variation from which several races have been differentiated (Wellhausen et al. 1957). It also constitutes the food base of the indigenous and mestizo communities of the State of Chiapas, as well as of the North and South Sierras of Oaxaca (Aragón *et al*., 2006, CONABIO 2011, Wellhausen *et al*., 1951).

Figure 9.1 Maize landraces from Mexico

Source of reference: Courtesy CIMMYT Maize Germplasm Bank, 2019

Normally, the nixtmalization is carried out with white and yellow corn, either by culture or custom or consumer demand, however in some states such as Chiapas, due to having a diversity of pigmented corn maizes, they tend to use this technology to obtain corn products nixtamalized, in addition to being foods with great potential for the supply of colorants and beneficial antioxidants for health, such as anthocyanins (Cadena-Iñiguez, 2018).

Nixtamalization is the process by which the corn is cooked with water and calcium hydroxide, to obtain the nixtamal that, after grinding, gives rise to the nixtamalized dough used to make tortillas, tamales, etc. There are some documents that indicate that nixtamalization was originated in Mesoamerica (specifically in the Mexican highlands).

Alternative processes in Nixtamalization

Bressani *et al*., (1962) evaluated a procedure based in the coccion corn under pressure of 0.35 and 1.05 kg/cm^2 in dry and humidity conditions, for 15, 30 and 60 minutes, without using lime. This method reduced the crude fiber content, which is one of the specific effects of lime, and the calcium content was significantly lower than that of the dry dough produced in the traditional method.

Molina *et al*., (1977), reported the preparation of instant flours by coccing and drying a mixture of corn with water (ratio 1:3) and lime (0.3% w/w) in a double rotating drum. The process conditions were: pressure of 15, 20 and 25 psi, thereby reaching temperatures of 93, 99 and 104 ° C, respectively at 2, 3 and 4 rpm. In this study, the flour was hydrated and tortillas were made, obtaining physicochemical and sensory characteristics similar to the tortillas obtained by the traditional method.

Johnson *et al*., (1980), proposed an instant flour process by micronization, which is a dry processing method, using infrared gas burners. This procedure was to mix the broken corn kernels in a dilute calcium solution and subsequently the mixture was subjected to infrared cooking. The tests obtained for texture and rollability in tortillas were similar to tortillas made from commercial instant flour.

Khan *et al*., (1982) compared three methods: the traditional, a commercial one and pressure coccion in the laboratory. The corn was subjected to sub coccion, optimal coccion and over coccion in order to measure some physical and chemical changes that could occur. Although the traditional method caused the greatest loss of dry matter from the maize, it produced the best tortillas in terms of texture, color, and acceptability. The pressure coccion method in the laboratory gave sticky batter and unsightly looking tortillas and the commercial gave less appetizing looking tortillas.

Contreras (2009) proposed using ohmic heating for the production of instant corn flour. Treatments were evaluated using conditions of humidity of 45%, 53% and 60%, temperatures of 70 °C, 80 °C and 90 °C, and particle sizes of maize 0.5, 0.8 and 1.3 mm.

The best treatment was the one that had similarities in the retrogradation and luminosity of the flour; and the adhesion, cohesion, moisture and yield of the dough. In relation to the tortillas, similarities were found in color and rollability, in addition to the fact that the ohmic process efficiently preserves the protein content present in the original corn. Therefore this method can be a production alternative for instant corn flours.

Contreras (2015), mentions that the cold nixtamalization of corn obtained by an extruction method produces interaction of corn with excess water and calcium hydroxide, which irreversibly modifies its viscosity and structure properties. In addition to the fact that the standing time without heating causes swelling and morphological changes in the corn starch, all these factors can guide a process that improves the quality of processed corn products.

Currently, research has been dedicated to not replacing the traditional nixtamalization process, but on the contrary, seeking improvements either in some modification of the process, use of equipment or emerging technologies in order to optimize the process and obtain quality characteristics. similar to those of a traditional Nixtamalization and acceptable to the consumer.

3 Methodology

The development of the project was carried out in the laboratories of the Technological University of La Selva. The vegetative material was collected in 2019 in different localities of the municipality of Ocosingo, Chiapas. The races landraces evaluated were Olotón of white, yellow, purple and red color.

Description of traditional Nixtamalization

The first step of traditional nixtamalization consisted in coccing the corn kernels in an alkaline solution of calcium hydroxide (1-2%) at a temperature close to the boiling point. After coccion, the corn remained in the broth (nejayote) for 8 h. Coccion and steeping times for corn varied depending on the type of corn, hardness of the grain, and local traditions. In the region of Ocosingo, Chiapas., farmers can be perform the coccion from a few minutes to an hour, and leave it soaking from a few minutes to about a day, it is not yet a standardized process.

To know if the process was successful, it was verified that the corn grain could be easily peeled between the fingers when rubbing it. Subsequently, the grains were completely washed to clean them of the remains of the nejayote, the pericarp was discarded and only the germ of the grain was preserved. Afterwards, the grain was tritured with a manual disk mill to obtain corn dough or flour.

Description of cold Nixtamalization

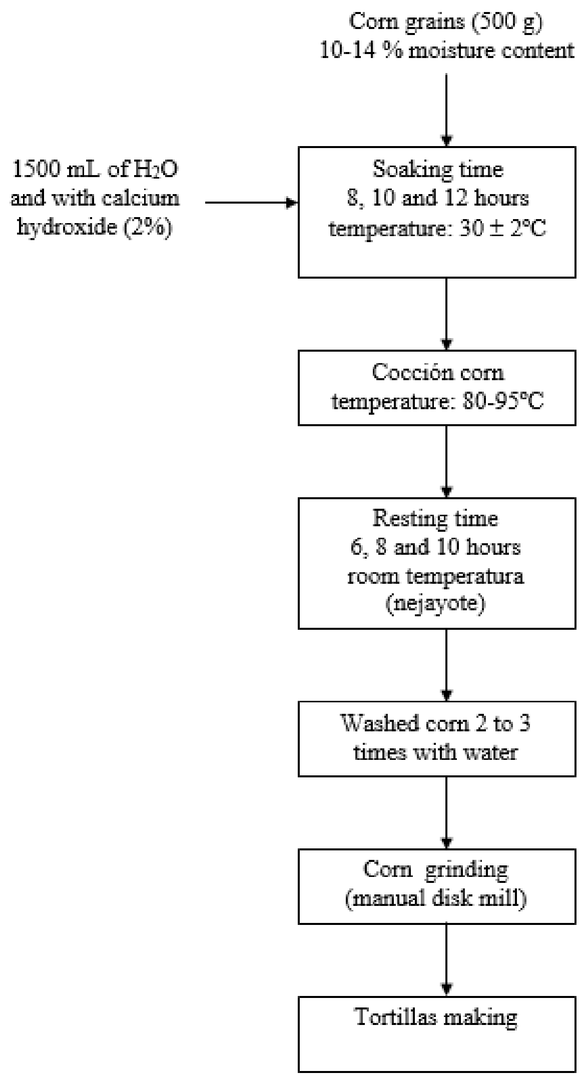
Corn grains (500 g) were placed in plastic containers for a soaking stage with 1500 mL of H_2O and with calcium hydroxide concentrations (food grade) of 2%. The containers were kept closed at room temperature (30 ± 2ºC) for 8, 10 and 12 h.

Afterwards, the cocción of corn grains were made at a temperature of 80-95 °C, the coccion time was verified by cutting a kernel and visually inspecting that it had partially gelatinized on the periphery and softened the grain. Then a resting time of 6, 8 and 10 h of the corn grains was carried out in the nejayote at room temperature. Subsequently, it was washed 2 to 3 times with water until the excess of lime was eliminated.

To obtain the dough, a manual disk mill and worm screw feeder were used, adding an average of 100 mL of water, in each grinding, to obtain the pasty texture and soft, characteristic of the dough produced by the traditional nixtamalization method.

The variables evaluated in the process were: grain moisture, coccion time, yield (dough/corn), pH of the nejayote, dough moisture and number of tortillas obtained.

Figure 9.2 Diagram of cold nixtamalization process



Moisture Analysis (dry grain, nixtamal and dough)

Samples of 0.5-1.0 g, randomly selected from each treatment, were analyzed and placed in an oven at a temperature of 130 ± 3 °C for four hours, then left to cool for 45 minutes and the weight was recorded to calculate the content of moisture (AACC, 2000).

pH determination (nejayote)

It was based on the electrometric measurement of the activity of the hydrogen ions present in a 5-10 ml sample, it was gently stirred for 30 seconds and the pH was measured with a potentiometer.

Experimental design

A completely randomized design with factorial arrangement A x B x C with three replications per treatment was used for the study. The factors evaluated were soaking times with three levels (8, 10 and 12 h), resting times (6, 8 and 10 h) and the maize landraces with 4 levels (factor C). The analysis of the results was processed through an ANOVA and a comparison of means, using the Tukey test ($p \leq 0.05$) using the statistical software R-studio version 3.1.1.

Preparation of tortillas

About 25 g of dough was taken and 11.5-12 cm diameter discs were formed using a metal hand press. The discs were placed on a stainless steel griddle conditioned with a lime solution, heated to a temperature of 200 °C ± 20 °C, the tortillas were cooked alternately on both sides in times no longer than 30 seconds, and later they were deposited in a container covered by a cloth blanket for later analysis. The variables evaluated in the tortillas were: rollability and degree of inflation through hedonic scales.

Tortilla properties analysis

Degree of inflation of the tortilla

The tortillas were evaluated during cooking, through the following scale: 1) tortilla with full inflation, 2) intermediate inflation and 3) without inflation (Jiménez – Juárez *et al*., 2012).

Tortilla rollability

It was determined by rolling the tortilla, through the following scale: 1) tortilla without rupture, 2) with an approximate break of 25%, 3) with an approximate break of 50%, 4) with an approximate break of 75% and 5) with complete rupture (Bedolla, 1984).

4 Results

Before starting the nixtamalization process, the corn grains were characterized, observing that the four genotypes had a standard moisture condition between 10-14%. Moisture is an parameter that indicates that the corn is ready to be stored or used in nixtamalization process. (NMX- FF-034/1-SCFI-2002). The moisture differences between the studied maize landraces were not significant, indicating that the corn grains used were homogeneous at the beginning of the study (Table 9.1).

Table 9.1 Moisture content in maize landraces of Chiapas, Mexico

Maize landraces	Moisture of corn grain (% w.b)
White corn	11.385[a]
Yellow corn	11.498[a]
Red corn	10.195[a]
Purple corn	11.023[a]

Averages with the same letters are not statistically different (Tukey, $p<0.05$)

It is important to mention that in order to evaluate the "Cold Nixtamalization" process, the traditional nixtamalization was first characterized in the four genotypes, since it is a thermal process that requires a combination of temperature and times, in addition, a highly relevant factor is the genotype of corn that is used, since each type has qualities that can give it a different texture and flavor to the final product.

Table 9.2 Traditional Nixtamalization in maize landraces

Genotypes	Moisture content of nixtamal (% w.b)	Coccion time (minutes)	Dough yield (g mass/g dry corn)	Dough moisture (% w.b)	Nejayote pH
White	41.61033[a]	70.06667 [a]	0.9352 [a]	58.4247 [a]	10.65 [a]
Yellow	41.03133 [a]	70.09333 [a]	0.8910 [a]	53.5993 [a]	10.84 [a]
Red	42.50167 [a]	60.3533 [a]	0.9136 [a]	50.8980 [a]	11.80 [a]
Purple	46.18167 [a]	66.8466 [a]	0.9603 [a]	59.6760 [a]	11.53 [a]

Averages with the same letters are not statistically different (Tukey, $p<0.05$)

In Table 9.2 it is observed that there is an increase in the moisture of the corn grain during coccion and rest times of the process, so that the nixtamal reached values around 41- 46% moisture content and is similar to that reported by Serna - Saldivar *et al*., 1990. According to the standard, when a moisture value of no more than 42% is reached, they are very hard maizes, which do not retain much pericarp, since the moisture of the nixtamal is given both by endosperm and by pericarp attached to the grain. The values obtained in the genotypes evaluated indicated that they are very hard maize, where the diffusion of water into the grain is slow due to its structural composition, and to achieve the increase of the moisture in nixtamalization, its necessary to apply prolonged periods of process. It is also observed that in the other variables evaluated, such as coccion time, dough yield, dough moisture and pH of the nejayote there are no significant differences, in addition to being in adequate ranges to obtain tortillas with industrial quality accepted by the consumer. Because when it comes to "quality", it is about tortillas that must meet certain sensory and rheological properties that allow them to have accepted aroma, flavor, flexibility and texture characteristics, as well as that they can be folded and rolled.

Evaluation of Cold Nixtamalization

Based on the results in traditional nixtamalization, a single genotype (white) was selected to standardize the cold nixtamalization process through the study of soaking times before coccion and rest times in the nejayote, parameters considered critical during nixtamalization, and they are variable that are sometimes determined based on the experience and customs of the farmers (Milan-Carrillo *et al*., 2004). In Table 9.3, the best treatments are presented in relation to the parameters evaluated in the standardization of cold nixtmalization process.

Figure 9.3 Genotype of white corn with cold nixtamalization

Table 9.3 Standardization of cold nixtamalization

Soaking and resting time (hours)	Cocción time (minutes)	Corn weight (g)	Dough weight (g)	Tortillas number	Tortillas weight (g)	Tortilla rollability (% break)	Degree of inflation of the tortilla
12-6	43.0 ^{b}	791.50 ^{a}	1023.00 ^{b}	40.0 ^{a}	736.60 ^{b}	75 % ^{b}	Intermediate
12-8	40.0 ^{c}	804.00 ^{b}	1075.25 ^{d}	41.0 ^{b}	738.10 ^{b}	100% ^{a}	Full
12-10	43.0 ^{b}	861.00 ^{d}	1057.00 ^{c}	40.0 ^{a}	785.50 ^{d}	100% ^{a}	Intermediate
10-6	43.5 ^{b}	802.00 ^{b}	1011.00 ^{a}	41.0 ^{b}	715.50 ^{a}	100% ^{a}	Full
8-6	50.5 ^{a}	816.75 ^{c}	1074.00 ^{d}	43.0 ^{c}	765.75 ^{c}	100% ^{a}	Full

Averages with the same letters are not statistically different (Tukey, $p<0.05$)

Table 9.3 shows that the combination consisting of 12 hours of soaking and 8 hours of rest, is a condition that minimizes the coccion time and also presents a statistically similar performance to the other treatments, which makes it the selected scheme. The results show that in the study with very hard maize, the soaking time before cooking contributes to the diffusion of the water towards the grain, softening and detaching the husk from the maize. This pretreatment with the combination of the standing time facilitates the absorption of water in the grain, and this contributes towards a reduction in the coccion time and in turn with the fuel consumption. From the parameters selected in the Cold Nixtamalization, The table 9.4 shows the results of the four maize landraces using both processes, the traditional and the cold one.

Table 9.4 Comparison of cold and traditional nixtamalization of the four maize landraces

Nixtamalization												
	Traditional method						Alternative method (Cold)					
Genotypes	Coccion time (minutes)	Dough yield (g mass/g dry corn)	Tortillas (#)	Rollability (%)	Degree of inflation (%)	Nejayote pH	Coccion time (minutes)	Dough yield (g mass/g dry corn)	Tortillas (#)	Rollability (%)	Degree of inflation (%)	Nejayote pH
G1	70.07 ^{a}	1.04 ^{a}	39 ^{a}	100 ^{a}	94.0 ^{a}	10.65 ^{a}	40.15 ^{a}	1.12 ^{a}	38 ^{a}	100 ^{a}	100 ^{a}	9.86 ^{b}
G2	70.09 ^{a}	1.11 ^{a}	35 ^{a}	100 ^{a}	98.2 ^{a}	10.84 ^{a}	41.80 ^{a}	1.07 ^{a}	37 ^{a}	100 ^{a}	100 ^{a}	10.98 ^{a}
G3	68.43 ^{a}	0.97 ^{a}	37 ^{a}	100 ^{a}	93.0 ^{a}	11.80 ^{a}	41.10 ^{a}	0.99 ^{a}	38 ^{a}	100 ^{a}	100 ^{a}	11.65 ^{a}
G4	66.84 ^{b}	1.11 ^{a}	38 ^{a}	100 ^{a}	100 ^{a}	11.53 ^{a}	39.50 ^{a}	1.12 ^{a}	38 ^{a}	100 ^{a}	100 ^{a}	11.40 ^{a}

Averages with the same letters are not statistically different (Tukey, $p<0.05$)
(Maize landraces: G1= White, G2= Yellow, G3= Red, G4= Purple)

Figure 9.4 Genotype of yellow corn with cold nixtamalization

Figure 9.5 Comparison of red corn tortillas with traditional and cold nixtamalization

Taking the results of Table 9.4 as a reference, it is observed that there is a decrease in the coccion time by the cold nixtamalization method around 40%, this is due to the fact that the resting time (pre-treatment) and soaking contributes to soften the corn grain and allows both water and lime to perform nixtamalization more easily since biochemical reactions, cross-linking and molecular interactions occur in it. These changes modify the physicochemical, structural and rheological characteristics of the dough, as well as the structural and textural properties of the tortilla produced. In addition, this reduction in time contributes to reducing coccion time, fuel costs and therefore process costs.

In relation to the other variables evaluated such as dough yield, number of tortillas, rollability, inflation and pH of the nejayote, in most of them, no significant differences are observed between the four genotypes, and those differences observed as in the case of the nejayote of the white genotype could be attributed to experimental errors. It is also observed that there is no significant difference in traditional and cold nixtamalization in relation to the characteristics of the final product, which allows positive results in the tortilla industry sector.

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6 Conclusions

Through the evaluation of the four maize landraces, key processes of traditional nixtamalization were detected and similar results can be obtained if the process is carried out with a control of the process parameters and similarity of the physicochemical characteristics of the corn grain.

An alternative method called "Cold Nixtamalization" was evaluated considering a pretreatment before the process and standardization of the resting time of the corn in the water of the nejayote, and according to the results of physicochemical tests carried out on the mass and tortilla, it was verified that it can be a suitable method to be implemented because it reduces the coccion time, guaranteeing a decrease in fuel consumption in the process.

With the specifications of the alternative method, the evaluation was carried out in the four genotypes (white, yellow, red and purple) and their comparison with the traditional method, obtaining rheological and sensory characteristics of similar tortillas in the two methods.

The implementation of this alternative method favors the integral improvement of the process, reducing energy consumption during coccion time, without the need to use additives or equipment to maintain the quality of the dough and tortillas, similar to that of traditional nixtamalization process.

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