Physical-chemical characterization of local maize from Chiapas, Mexico

Caracterización físico-química de maíces locales de Chiapas, México

Caracterização físico-química do milho local de Chiapas, México

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Abstract

The physical-chemical quality of maize has become important for the food industry, so it is a condition for the selection of any local cultivar or improved varieties. The physical-chemical quality of local maize from La Sepultura Biosphere Reserve (REBISE), Chiapas, was characterized, to demonstrate that the maize diversity in the reserve presents potential for the flour and tortilla industry in Mexico. Collections of eighteen local maize populations associated with different races and two commercial hybrid materials were evaluated. Nineteen variables were characterized using multivariate techniques of Factor Analysis and Clusters. By reduction of data, six components were extracted. Typology of maize varieties merged into four groups: Group I) Of high projection in the components of breaking strength (Fu Rup RE, 300.25 gf) and pericarp dissolution (pericarp, 5.39 %; retained pericarp, 47.91 %); Group II) also high scoring in breaking strength and its persistence (Fu Rup RE, 277.25 gf), but low scoring for grain consistence and protein yield (flotation index 24.50); weight of 100 grains 33.31 g, (grain proteins 9.94 %); Group III) presented greater projection in the component of grain density, and moisture of the "nixtamal" and the dough (hectoliter weight 73.5 kg-hl, elongation 13.60 mm, dough moisture 57.95 %, Fu Rup RE, 220.83 gf); Group IV) showed lower projection in "nixtamal" moisture (44.48 %) and dough, so as elasticity of the "tortillas" (12.94 mm). The physical-chemical variables contributed to identify cultivar groups on the quality of the grain.

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Resumen

La calidad físico-química del maíz ha adquirido importancia para la industria alimenticia; por lo que es una condición para la selección de germoplasmas mejorados. Se caracterizó la calidad físico-química de maíces locales de la Reserva de la Biosfera La Sepultura (REBISE), Chiapas; para demostrar que la diversidad existente en la reserva, presenta potencial para la industria de la harina y la "tortilla" en México. Se evaluaron colectas de 18 poblaciones de maíces locales asociadas a diferentes razas y dos materiales híbridos comerciales. Se caracterizaron 19 variables, mediante técnicas multivariadas de Análisis Factorial y Conglomerados. Por reducción de datos se definieron seis componentes. Las tipologías fueron: Grupo I) de alta proyección en los componentes de fuerza de ruptura (Fu Rup RE, 300,25 gf) y dilución del pericarpio (pericarpio, 5,39 %; pericarpio retenido, 47,91 %); Grupo II) también de alta puntuación en la fuerza de ruptura (Fu Rup RE, 277,25 gf), pero bajas puntuaciones para la consistencia del grano y rendimiento proteico (índice de flotación, 24,50); peso de 100 granos de 33,31 g (proteínas del grano 9,94 %); Grupo III) presentó mayor proyección en el componente de densidad del grano y humedad del nixtamal y la masa (Peso hectolítrico, 73,5 kg^{-hl}; elongación 13,60 mm; humedad de la masa 57,95 %; Fu Rup RE, 220,83 gf); Grupo IV) mostró menor proyección en la humedad del nixtamal (44,48 %) y la masa, así como elasticidad de las tortillas (12,94 mm). Las variables físico-químicas contribuyeron a identificar agrupaciones de cultivares sobre la calidad del grano.

Palabras clave: *Zea mays*, cultivares, granos

Resumo

A qualidade físico-química do milho tornou-se importante para a indústria alimentar e é, portanto, uma condição para a selecção de germoplasma melhorado. Caracterizou-se a qualidade físico-química do milho local da Reserva da Biosfera La Sepultura (REBISE), Chiapas; para demonstrar que a diversidade existente na reserva tem potencial para a indústria de farinha e tortilha no México. Foram avaliadas coleções de 18 populações locais de milho associadas a diferentes raças e dois materiais híbridos comerciais.19 variáveis foram caracterizadas por meio de técnicas multivariadas de Análise Fatorial e Clusters.Por redução de dados, seis componentes foram definidos. A tipologia gerou quatro grupos: Grupo I) com alta projeção nos componentes da força de ruptura (Fu Rup RE, 300,25 gf) e diluição do pericarpo (pericarpo, 5,39%; pericarpo retido, 47,91%); Grupo II) também pontuou alto na força de ruptura (Fu Rup RE, 277,25 gf), mas pontuações baixas para consistência de grãos e rendimento de proteína (índice de flotação, 24,50); peso de 100 grãos de 33,31 g (proteínas dos grãos 9,94%); Grupo III) apresentou maior projeção no componente densidade de grãos e umidade de "nixtamal" e massa (peso hectolitro, 73,5 kg^{-hl}; alongamento 13,60 mm; umidade da massa 57,95%; Fu Rup RE, 220,83 gf); Grupo IV) apresentou menor projeção na umidade do "nixtamal" (44,48%) e da massa, bem como elasticidade das tortilhas (12,94 mm). As variáveis físico-químicas contribuíram para identificar agrupamentos de cultivares na qualidade do grão.

Palavras-chave: *Zea mays*, cultivares, grãos

Introduction

The maize crop is prone to develop local variability due to its allogamous condition. This variability is manifested from the morpho-agronomic aspects of the cultivars, to the physical and chemical characteristics of the grains. The diversity of maize has its origin in the interactions between human, cultural, environmental, management, use factors, among others, since its domestication and its distribution through various routes to the entire cultural region of Mesoamerica (Guevara *et al*., 2020).

In this way, the crop developed adaptation to extreme conditions of altitude, fertility and climate, among other variables of its environment. Only in Mexico, at least eight racial groups are recognized (ancient indigenous, exotic, pre-Columbian, "mestizo", prehistoric, incipient modern, races not well defined and unclassified races), with 59 races and a large intra-racial morphological diversity, mainly in cobs and grains, as well as phenological cycles; however, this diversity is also subjected to cultural and economic issues (Hernández-Ramos *et al*., 2020). This fact leads to the reasoning that culture and economics ultimately impose guidelines on the indirect selection of the physical and chemical characteristics of the grains, flours and "tortillas" produced.

Scientific research framed in the physical and chemical properties of maize, must take on the challenge of recognizing the cultural contexts and commercial interests as factors that define the desirable properties and the local diversity of maize (Guevara *et al*., 2020 and NMX-FF-034/1-SCFI-2002, 2002, p.1-22); as well as the complexity of relationships between the variables of grain quality and the "tortilla" (Vázquez-Carillo *et al*., 2020), which leads to the hypothesis of the differentiation of local maize from the physical-chemical characteristics of the grains, by limiting the potential for the flour and "tortillas" industry. However, the simple approach of this hypothesis could have a secondary relevance given the need to unravel the interactions and relationships between these individual variables that ultimately define the general properties and underlie these local differences.

In the present research, the objective was to characterize the physical-chemical quality of local maize cultivated in La Sepultura Biosphere Reserve (REBISE), Chiapas; in order to answer the following question: ¿What relationships exist between the physical and chemical variables of the grains that allow typifying and characterizing the local maize in the Frailesca region in relation to the potential for the flour and "tortilla" industry and to demonstrate that the existing diversity in the reserve has potential for the flour and "tortilla" industry.

Materials and methods

Study area and sample

The study was carried out in nine communities of the REBISE, located in the southwestern region of the state of Chiapas, in the northwestern portion of the Sierra Madre de Chiapas.

It is a territory shared by the municipalities of Arriaga, Cintalapa, Jiquipilas, Tonalá, Villa Corzo and Villaflores; geographically, it is located between parallels 16º00'18'' and 16º29'01'' north latitude and meridians 93º24'34'' and 94º07'35'' west longitude.

In the REBISE there are climates of type A(C)m(w) (semi-warm humid), AW2(w) (warm sub-humid), with abundant rainfall in summer. Eutric regosol soils predominate and in the vegetation we can find mesophilic mountain forest, pine-oak, as well as agricultural areas (Hernández-Ramos *et al*., 2020).

Eighteen local varieties of rainfed maize were collected, during November and December 2019, in correspondence with the following criteria: presence, distribution, prevalence and permanence within and between communities. Three kilograms of maize were collected and stored at room temperature, without the application of chemical products. Commercial hybrids H-WP8063 and H-27 also grown in the study area were included in the research (table 1).

Table 1. Description of local maize varieties sampled in La Sepultura Biosphere Reserve, Chiapas, Mexico.

Local variety	Place of collection	Related race[†]	Acronym
Amarillo	California	Olotillo + Tepecintle + Tuxpeño	AmarilloC
Precoz	California	Tuxpeño (GA) + Vandeño	PrecozC
Maíz Negro	California	Olotillo + Vandeño + Tuxpeño	Maíz Negro
Crema	California	Tuxpeño (GA) + Tepecintle	Crema
Jarocho	Tres Picos	Tuxpeño (GA) + Vandeño	JarochoTP
Precoz	Tres Picos	Tuxpeño (GA)	PrecozTP
Huesito	Tres Picos	Olotillo + Tuxpeño + Conejo	Huesito
Amarillo	Ricardo Flores Magón	Tuxpeño (GA)	AmarilloRFM
Jarocho	Ricardo Flores Magón	Tuxpeño (GA)	JarochoRFM
Tornamil	Ricardo Flores Magón	Tuxpeño (GA)	Tornamil
Jarocho	Villahermosa	Olotillo + Tuxpeño + Vandeño + Tepecintle	JarochoV
Olote Rojo	Nueva Esperanza	Tuxpeño (GA) + Vandeño	Olote Rojo
Pollito	Ricardo Flores Magón	Without classification	Pollito
Jarocho	El Triunfo	Tuxpeño (GA) + Vandeño	JarochoET
Amarillo	Villahermosa	Tuxpeño (GA) + Olotillo + Tepecintle	AmarilloV
Amarillo	Josefa Ortiz de Domínguez	Olotillo + Tepecintle	AmarilloJOD
Morales	La Sombra de la Selva	Tuxpeño (GA) + Olotillo + Tepecintle	Morales
San Gregorio	La Sierrita	Tuxpeño (GA) + Vandeño	San Gregorio

[†]The race relationship described here was defined by the authors according to the classification made by Wellhausen *et al*. (1952).
The race in the first place is the characteristic that most predominates in the maize population. GA: Advanced generation.

Variables used for characterization

For the physical-chemical analysis of maize from the National Institute of Forestry, Agricultural and Livestock Research (INIFAP), Texcoco, state of Mexico, 19 physical and chemical variables were chosen for the evaluation of grain and "tortilla" quality, with two repetitions. The measurements and the processing of the samples were carried out using the methodologies described by Salinas and Vázquez (2006).

The variables evaluated were: grain moisture, hectoliter weight by method 84-10 (American Association of Cereal Chemists [AACC], 2000, 350), flotation index (Salinas *et al*., 1992), weight of 100 grains, percentage of pedicel, pericarp and germ. "Nixtamal" quality was evaluated based on the variables of "nixtamal" moisture, loss of solids and retained pericarp. For the quality of the dough and the "tortilla", the variables of freshly made and 24 h "tortillas" were evaluated, as well as moisture, elongation and breaking strength, and "tortilla" yield (Salinas and Vázquez, 2006). Protein and tryptophan content in grain and "tortilla" were also evaluated with Technicon Instruments equipment (Galicia-Flores *et al*., 2011).

Nixtamalization and "tortillas" processing

One hundred grams of grain, in 1 % calcium oxide and 200 mL of distilled water were used. The components were mixed in 600 mL of water and heated to boiling. The boiling time was in correspondence with the hardness of the grain. The samples were left at rest for 14-16 h at room temperature (Salinas and Vázquez, 2006).

Treatment and data analysis

A data matrix of order $A_{(21,20)}$, was formed, placing the 18 varieties by rows and the 19 characterization variables by columns. To reduce the dimensionality of the characterization variables, a Factor Analysis was applied, by the principal components (PCA) method, in which the components with eigenvalues greater than one (1) were assumed and that as a whole managed to explain more than 75% of the total variability (Tovar and García, 2017). The extracted components were considered new variables, labeled according to their relationships with the original variables, and were used in cluster analysis to form local maize clusters, using Ward's method. These groupings were validated using ANOVA for linear models and descriptive statistics of the original variables. Statistica software, version 8.0 was used for the analyses (StatSoft, 2012).

Results and discussion

The PCA reduced the dimensionality of the 19 variables to 6 components, which were able to explain 77% of the total variance. Table 2 shows the variables associated with each principal component (PC) and the explained variance. These PC are defined as: I) Flotation index and grain protein, II) Hectoliter weight, "nixtamal" and dough moisture; III) Remaining pericarp, IV) Breaking strength, V) "tortilla" moisture and VI) Percentage of solids.

In PC I, the highest proportion of the germ is associated with the increase in grain and "tortilla" proteins (table 2). The germ contains an important protein fraction and it is not lost during the nixtamalization (Paredes-López *et al.,* 2009). PC II is described by the association of a lower hectoliter weight with a higher proportion of moisture in the "nixtamal" and dough. Hardness influences the structural composition and therefore the composition of water assimilated by the grain (Arámbula-Villa *et al*., 2004).

The behavior after nixtamalization is one of the main aspects of maize quality for the flour and "tortilla" industry. It was found that during this process the variables acquire independence as the transformation to "tortilla" takes place; as reflected in the separation of the components. PC II describes the remaining pericarp that according to Salinas and Vázquez (2006) favors plasticity, dough manageability and "tortilla" softness. PC IV is associated with breaking strength; according to Vázquez-Carrillo *et al*. (2014) this variable is linked to "tortilla" texture and, therefore, to the oil content of the grain. PC V is described by the "tortilla" moisture, which is not always associated with higher "nixtamal" moisture, because the loss of water depends on factors such as thickness, temperature and cooking time (Arámbula-Villa *et al*., 2004); it is also not a determinant in "tortilla" texture (Salinas-Moreno *et al*., 2010). PC VI by percentage of solids refers to the pericarp retained during cooking (Vidal-Martínez *et al*., 2008).

Table 2. Association of variables and explained variance of the PC obtained for the grouping of local maize from La Sepultura Biosphere Reserve, Chiapas, Mexico.

PC	Associated variables	Eigenvalue	Explained variance (%)
I. Flotation index and protein in "tortilla" and grain	Flotation index (-0.60), Weight of 100 grains (0.63), Pedicel (-0.70), Germ (0.65), "tortilla" protein (0.72) and grain protein (0.89)	4.88	23.24
II. Hectoliter weight, "nixtamal" and dough moisture	Hectoliter weight (-0.87), "nixtamal" moisture (0,72), dough moisture (0.82) and Elongation RH (0.63)	3.58	40.31
III. Remaining pericarp	Pericarp (0.82), Retained pericarp (-0.70) and "tortilla" yield (-0.79)	2.56	52.49
IV. Breaking strength	Breaking strength RH (0.66), Breaking strength at 24 h (0.88)	2.21	63.01
V. "Tortilla" moisture	"Tortilla" moisture (0.77), "tortilla" moisture at 24 h (0.93)	1.59	70.59
VI. Percentage of solids	Percentage of solids (0.89)	1.36	77.05

RH: freshly made. PC: Principal Components.

However, the non-correlation of the components is paramount in the reduction of original variables to justify the variance represented (Tovar and García, 2017). For example, the idea that the variables of hectoliter weight and flotation index are related to grain hardness is assumed. Both are inversely correlated, the higher the hectolitric weight maize has, the harder it will be and its flotation index will be lower. However, in the results obtained in the present study, these two variables were located in different components (PC II and PC I, respectively). This raises a new hypothesis of interaction with other variables, where the variation of one could be independent of the variation of other; therefore, it is necessary to conduct studies in this sense, which contribute to enriching the interaction between the different variables.

Cluster Analysis (Maize groups)

Base on the factor scores, cluster analysis was performed, resulting in four main groups and two varieties. The dendrogram (figure 1) shows two local varieties and the four groups of varieties. Figure 2 shows the differential aspects between groups.

In turn, figure 2 allows identifying the differential aspects between the groups.

The singular varieties were H-WP8063 and Pollito. The first is a commercial hybrid and was projected with low scores in the grain consistency component and protein content, and the breaking strength component and its persistence. The Pollito variety was characterized by a high projection in the pericarp dissolution component and percentage of solids. This indicates that a large amount of pericarp is released and remains suspended in the "nejayote" (residual liquid from nixtamalization).

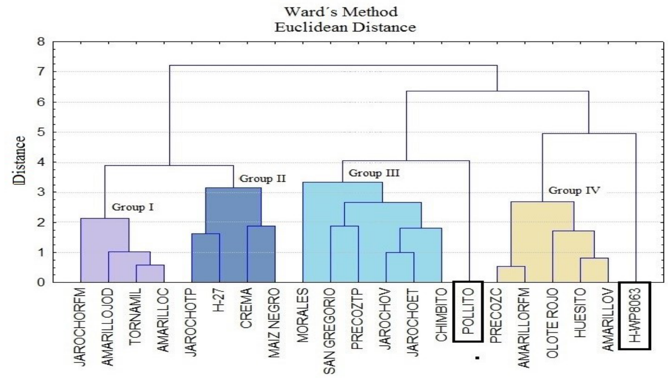

Figure 1. Grouping dendrogram of local maize varieties according to some physical-chemical characteristics of the grain.

Group I (GI) included four of them and was characterized by having a high projection in the PC III (pericarp dissolution) and PC IV (breaking strength and its persistence). Group II (GII) was composed of four varieties and was characterized by high scores for the breaking strength component and its persistence, but low scores for the grain consistency component and protein content (figure 1).

The group III (GIII) included six varieties. It presented higher projection in the moisture component of the "nixtamal" and the dough with more elastic "tortillas", grains of lower density and higher development and dissolution of the pericarp.

Group IV (GIV) was of five varieties. It showed the lowest projection within the moisture component of the "nixtamal" and dough, as well as elasticity of the "tortillas", with grains of lower density.

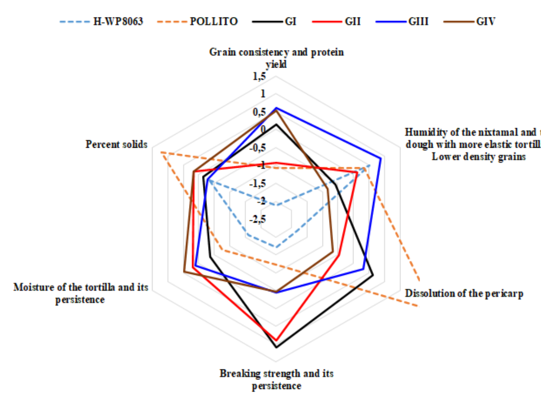

Figure 2. Differentiation between groups identified in the diversity of local maize characterized on the basis of the factor scores.

The variables combined in the first component differentiate the maize H-WP8063, Pollito and the group GII from de rest of the variables (figure 1). The maize H-WP8063 and Pollito, resulted of intermediate hardness and medium grains, according to their flotation indexes and weight of 100 grains. The Mexican Standard (NMX-FF-034/1-SCFI-2002, 2002, p.1-22), classifies maize with flotation indexes between 38 and 62 as semi-hard. The rest of the varieties studied are classified as hard, with flotation indexes between 18 and 25. For its, part group GII is classified as hard corn, but with small grains, similar to the H-WP8063 and Pollito varieties (table 3).

Table 3. Behavior of original variables that contributed to the classification of local maize groups in La Sepultura Biosphere Reserve, Chiapas, Mexico

Original variables	H-WP8063	Pollito	GI		GII		GIII		GIV		Sig
			Average	E.E.	Average	E.E.	Average	E.E.	Average	E.E.	
Flotation index	47.00	40.00	18.00	4.56	24.50	4.34	23.33	4.06	21.80	1.93	0.70
Weight of 100 grains (g)	24.87	30.46	41.35^{a}	1.01	33.31^{b}	1.10	39.13^{a}	2.06	39.39^{a}	1.03	0.02
Pedicel (%)	1.63	1.95	1.65^{ab}	0.14	1.79^{a}	0.11	1.52^{bc}	0.03	1.36^{c}	0.05	0.01
Germ (%)	7.49	8.45	8.83	0.25	8.34	0.11	8.95	0.25	8.90	0.09	0.20
Protein in grain (%)	9.30	10.00	10.41	0.33	9.94	0.48	11.08	0.39	10.80	0.30	0.22
Protein in "tortilla" (%)	9.55	12.20	11.43	0.23	10.98	0.23	1208	0.38	12.05	0.46	0.16
Hectoliter weight (kg^{-hl})	74.17	75.36	77.01	0.91	75.25	0.91	73.50	1.67	76.82	0.35	0.16
"Nixtamal" moisture (%)	50.24	48.32	44.86	1.38	48.17	1.39	47.78	0.96	44.78	0.62	0.07
Dough moisture (%)	56.93	58.03	56.48^{b}	0.15	56.72^{b}	0.52	57.95^{a}	0.42	56.31^{b}	0.38	0.03
Elongation RH (mm)	13.99	12.76	13.09^{b}	0.19	13.84^{a}	0.20	13.60^{ab}	0.20	12.94^{b}	0.27	0.04
Pericarp (%)	4.36	6.37	5.39	0.06	4.98	0.25	5.35	0.08	5.09	0.13	0.15
Retained pericarp (%)	49.95	30.97	47.91	3.84	51.97	3.14	44.39	2.31	50.15	2.61	0.29
Fu Rup RE gf	230	214	300^{a}	14	277^{ab}	10	220^{c}	17	248^{bc}	13	0.01
Fu Rup 24 h	293	281.00	376^{a}	12	356^{a}	21	288^{b}	12	286^{b}	17	0.00

$^{a, b, c}$ Superscript letters per row indicate significant differences between Groups I, II, III and IV when applying Tukey's Test (Honest Significant Difference) (Winer *et al*., 1991). PCI and PCII cases were not included in the analysis of variance or in the multiple comparisons of means.

According to the criteria of Gómez *et al*. (2003), the grains of H-WP8063, Pollito and those included in GII are medium-sized grains (<33 $g.100^{-1}$ grains); the groups GI, GIII and GIV are large-sized (>36 $g.100^{-1}$ grains). Salinas and Vázquez (2006) used similar classification criteria, more than 38 g for large grains and between 33 and 38 g for medium grains. The Mexican flour industry requires medium-grain maize, while the dough and "tortilla" industry requires grains of this size or smaller, which hydrate more easily than large grains, favoring the yield of the high moisture products marketed (Salinas-Moreno *et al*., 2010). Likewise Sierra-Macías *et al.* (2016) used these classification thresholds in high protein quality cultivars to report that their grains were small in size; on the other hand, Coutiño-Estrada *et al*. (2008) reported values between 28 and 43 g. Grain size is a characteristic with great environmental influence. According to Salazar-Martínez *et al*. (2015), water regime is one of the environmental factors with significant influence on grain dimensions.

The proportion of germ was lower than those published by Salinas-Moreno *et al*. (2013). The germ must represent approximately 11.5% and contributes to the highest protein quality (Paredes-López *et al.,* 2009). The protein values, both in the grain and in the "tortillas", were lower than those indicated in improved maize (Coutiño-Estrada *et al.,* 2008) and in varieties of high protein value (Sierra-Macías *et al.,* 2016), but higher for other local varieties (Cázares-Sánchez *et al.,* 2015).

For this study, the grains with the highest protein content were the hardest (H-WP8063). Vidal-Martínez *et al*. (2008) argued that the direct proportionality relationship between hardness and protein content is given by a higher proportion of prolamins (zeins), majority fraction (50-70 %) in the protein of the maize endosperm, and deficient in the essential amino acids lysine and tryptophan; however, these authors reported a higher protein fraction (higher than 10.3 %) in improved varieties with grains of intermediate hardness. However, grain hardness is mainly associated with the proportions of floury and crystalline endosperm. Maize with soft endosperm have lower densities, with a value of 63-87% of the flotation index; compared to very hard or hard grains, which have 0-12 and 13-37 % of flotation index, respectively (NMX-FF-034/1-SCFI-2002, 2002, p.1-22; Salinas and Vázquez, 2006).

According to Salinas-Moreno *et al*. (2010), the percentage of pedicel in maize grain is relevant in the dough and "tortilla" industry (NMX-FF-034/1-SCFI-2002, 2002, p.1 -22), because this structure is made up of lignin, and it is not hydrolyzed during nixtamalization, although it acquires a dark hue that affects the appearance of the "tortilla", since the higher the percentage, the greater the abundance of black spots on the surface. For this reason, the flour industry eliminates this structure during the screening process. Even so, it establishes a maximum of 2% of pedicel. All cultivars considered in this study met this requirement.

The physical-chemical indicators of the second component allow differentiating the maize from the group GIII. Characteristics such as: lower density grains (according to hectolitric weight), higher humidity of the "nixtamal" and dough, as well as higher elongation of the "tortillas", are combined. On the other hand, the varieties included in groups GI and GIV were the ones with the most discrete behaviors in these variables.

The observed hectoliter weight classifies them as suitable for the flour industry, with values higher than 74 kg^{-hl}, according to the indicators established in the Mexican Standard for nixtamalized maize, although slightly lower in group GIII and those reported by Arellano-Vasquez *et al.* (2010)

The "nixtamal" moisture and dough moisture values coincide with those published by Sierra-Macías *et al.* (2016), somewhat higher than the maximum established by the Mexican Standard, 44% and 48% referred by Salinas-Moreno *et al.* (2010). The standard for the nixtamalized flour industry responds to certain requirements of industrial processes, storage and marketing. However, traditional and domestic processes do not strictly conform to these requirements. In this regard, Coutiño-Estrada *et al.* (2008) indicated that experience has shown that maize with characteristics outside these ranges are suitable for the traditional preparation of dough and "tortillas".

For "tortilla" quality, it is important that maize have the capacity to absorb water and retain it, which is reflected in "tortilla" yield (Vázquez-Carrillo *et al*., 2014). The "tortilla" yield values obtained in this research are higher than those reported by Sierra-Macías *et al*. (2016) and Coutiño-Estrada *et al*. (2008). This capacity is indirectly related to grain hardness and starch composition; the modification of the amylose/amylopectin ratio in the flours influenced the hardness and color of the "tortillas", as well as, the moisture conservation (Salinas-Moreno *et al.,* 2010).

Pericarp values are within acceptable ranges for the nixtamalized flour industry (4.5 to 5.5 mg) and are higher than those obtained for the Pollito variety and lower for H-WP8063. The retained pericarp values published by Coutiño-Estrada *et al.* (2008) are also similar with improved varieties in Chiapas. The flour industry requires values higher than 40 % in this indicator. Salinas-Moreno *et al*. (2010) mention that the pericarp is a structure made up of hemicellulose (> 50 %), cellulose (22 %), phenolic acids (5 %) and lignin (1 %). Therefore, hemicellulose is hydrolyzed by alkali during the nixtamalization process and transformed into heteroxylans associated with ferulic acid residues that have properties that favor dough and "tortilla" texture.

The breaking strength tends to be higher in the groups GI and GII; the values, both for freshly made "tortillas" and at 24 h, are similar to those published by Sánchez *et al.* (2007)."Tortilla" moisture coincides with that reported by Sierra-Macías *et al.* (2016) in maize of high protein quality and in ordinary maize. However, in improved varieties the tryptophan values were higher than 0.098 %. Regarding tryptophan in the "tortilla", a reduction in the percentage determined with respect to the grain was observed. "Tortilla" is the basis of the Mexican people's diet, representing about 70 % of the caloric intake in the lower income classes (Del Moral *et al*., 2015), hence the importance of considering its nutritional contribution.

Conclusions

The physical-chemical variables of the local maize studied were combined into six linear groupings or components. The first four were the ones that contributed the most to the characterization of groups and were labeled as follows: Component I, grain consistency and protein yield; Component II, "nixtamal" moisture and dough with more elastic tortillas and lower density grains; Component III, pericarp dissolution; and Component IV, breaking strength and its persistence. From the point of view of the physical-chemical characteristics combined in components, four typologies and two varieties (H-WP8063 and Pollito) that did not fit into any of these two groups could be defined.

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