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CHARACTERIZATION OF TORTILLAS MARKETED IN TLAZALA, MEXICO BY USING HIERARCHICAL CLUSTER ANALYSIS

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Abstract: *Tortillas are one of the most important foods for the Mexican's nutrition. The industrialization of the manufacturing process led to changes in final product quality. The aim of this study was to group and to identify the best tortilla from Tlazala, Mexico market. Ten industrial and artisanal samples were analyzed from chemical, textural and sensory point of view. Taking into account these characteristics, the samples were grouped by using hierarchical cluster analysis. The differences between groups were interpreted by mean comparison and analysis of variance. Three groups resulted, the first composed of machine made tortillas, the second from 100% maize grain nixtamalized in situ and the third comprised blue tortilla mechanically made from maize grain. The best characteristics were observed for the second group, mostly composed of artisanal tortillas. The results showed that the best tortilla is traditionally made, from 100% local maize grain, using a wood griddle.*

Keywords*: tortillas, cluster analysis, physico-chemical properties, sensory characteristics.*

1. Introduction

Maize products have a big importance in people from Latin-American diet. Maize tortillas are ones of the principal foods in Mexico, being consumed in both urban and rural areas [1]. In 2010, the annual consumption in urban areas was about 56.7 kg per capita, while in the rural areas was 79.5. Tortillas consumption brings an intake of carbohydrates, fibers, proteins, minerals and some vitamins [2]. Nowadays people are most interested in organic and traditional foods, this tendency increasing in the last 10 years [3].

The traditional maize tortillas production implies grains nixtamalization which means maize grains cooking with a slaked lime solution. This process has many benefits from both nutritional and sensory point of view, the grains becoming softer and easy to ground, the nutritional value being higher, the aroma being improved and the mycotoxins effects being decreased [1].

An increased maize consumption led to an industrialization of tortilla making processes which implies autoclaving and dough drying to obtain the nixtamalized industrial maize flour. This process modification had some consequences for

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the final product quality, since the aroma, texture and nutritional value are changed [1,4]. A study about the maize origin for tortilla making in Lakes Pátzcuaro and Zirahuén basins showed that for home made tortillas people use mostly local maize, while for those made with machines the maize comes from other regions of Mexico or they use industrial nixtamalized flour [5].

The characteristics of tortillas depend on the maize grain quality. For example, the starch content of maize grains directly influences dough moisture, texture, rheology and tortillas shelf-life. Thus, the origin of maize and physico-chemical characteristics affect final product properties [6]. Furthermore, the nixtamalization process conditions may also change tortillas quality, the texture, color and sensory profile of tortillas being determined by the solubilisation and diffusion processes that occur during lime cooking [4].

Tortillas are one the most important daily food for Mexican people. Thus, the final product quality knowledge may be of interest for both consumers and producers to choose properly or to improve product's characteristics. In this regard, the aim of this study was to characterize tortillas from Tlazala, Mexico market, to compare and to group them depending on the chemical, textural and sensory properties.

2. Materials and methods

2.1. Materials: Tortillas samples

Fresh tortillas were acquired from market at specialized shops called tortillerías in Tlazala town, Mexico and were kept in polyethylene bags at 4°C until analyses were performed or until drying at 55°C for 24 h and milling with a Tomas Willy mill with a 0.84 mm sieve.

Samples codes and characteristics are presented in Table 1.

Five tortillas types from different places were analyzed. From the industrial ones made up with machines, two were mixes of industrial maize flour and maize nixtamalized (TMX) *in situ*, two made of maize from other regions

(TMZ), two only of industrial maize flour (TMN) and one of blue maize from another region (TMA). All the artisanal tortillas (TA) were made of maize nixtamalized *in situ*, TA1 and TAA being cooked on gas hob, while TA2 was baked using a wood hob.

2.2. Methods

2.2.1. Chemical characteristics

Moisture content was determined according to the AOAC (1999) [7] method 925.098; ash content by method 923.03; fat content by Soxhlet extraction in petroleum ether (method 920.39C; proteins content by Kjeldahl method. Fibers contents (neutral and acid detergent) were achieved using an ANKOM 200 fibers analyzer [8]. Sugars contents were calculated by difference. The extract for polyphenols and antioxidant activity determination was prepared by methanol 80% extraction as it is described by Hernandez-Martinez et al. (2016) [9]. Polyphenols content was determined by Folin-Ciocalteu method, according to Hernandez-Martinez et al. (2016) [9] and the antioxidant activity expressed as inhibition percent (IC_{50}) was measured by the dilution method described by Iora et al. [10], lower values indicating high antioxidant activity. pH was determined according to the method described by Serena-Saldivar (2012) [11], by using an Oakton CON 510 pH-meter. All measurements were performed at least in triplicate.

2.2.2. Textural parameters

Tortillia's hardness was evaluated by using a TA.TX Plus Texture Analyser. According to the method described by Vaca-García et al. [12] a spherical probe perforated the sample pieces of 6.5 cm diameter hold by two metallic plates until they broke, at a speed of 10 mm s^{-1}. For each fresh sample nine measurements were performed.

2.2.3. Sensory characteristics

The sensory characteristics of fresh tortillas samples were evaluated by nineteen panelists with a 15 points scale, as it is described by Bejosano et al. (2005) [13].
The studied properties were color uniformity, surface uniformity, moisture, opacity, maize smell, lime smell, fermented smell, acid taste, salted taste, sweet taste, and lime taste. Also, the subjective textural characteristics of tortillas samples were achieved according to the method described by Morten Meilgaard, Gail Vance Civille, and Thomas Carr [14]. Thus, roughness, elasticity, hardness, masticability, moisture absorption and tooth packing characteristics were evaluated. A rolability test was performed by rolling the sample around a 13 mm diameter dowel and oticing the appearance of breakings [13].

2.2.4. Statistics

A hierarchical cluster analysis (HCA) using average linkage between groups was performed to see how the tortillas samples can be grouped and characterized, according to the chemical, textural and sensory characteristics that they present. To avoid the effects of high differences in mass concentration values the data were z-transformed. Groups of tortilla samples were formed by using the squared geometric Euclidian distance (Eq. 1) [15]:

$$\left(d_{x_i,x_i'}\right) = \sum_{j=1}^{J}\left(x_{ij} - x_{i'j}\right)^2 \quad (1)$$

where x_i and $x_{i'}$ are objects in the multidimensional space.

Table 1.

Tortillas samples characteristics

Sample	Purchase place	Maize source	Technology	Observations
TMX1		industrial maize flour and white maize	machine	
TMX2	tortillería	industrial maize flour and yellow maize	machine	
TMZ1	tortillería	white maize from the north of Mexico	machine	
TMZ2	tortillería	white maize from Sinaloa/Hidalgo	machine	preservatives addition
TMN1	tortillería	industrial maize flour	machine	
TMN2	tortillería	industrial maize flour	machine	
TA1	particular house	white maize from specialized shops	artisanal	wheat flour is added
TA2	particular house	local white maize, from Tlazala region	artisanal	
TMA	tortillería	blue maize from the north of Mexico	machine	
TAA	particular house	blue maize from specialized shops	artisanal	

The results were presented as a dendrogram comprising a hierarchical structure. The differences between clusters (significant at $p < 0.05$) were evaluated by applying to the cluster solution an analysis ofvariance (ANOVA) [16]. For the calculations SPSS 13.0 (trial version) software was used.

3. Results and discussion

The ten tortillas samples were grouped as function of the chemical, textural and sensory characteristics, as it is shown in the dendogram presented in Figure 1. According to the resulting dendrogram (Figure 1), the samples form three groups as it follows: the first group is composed of TMN1, TMN2, TMX1, TMX2 and TMZ1 which are made with machines, the second group comprises TA1, TA2, TAA and TMZ2 which contain only maize grains nixtamalized *in situ* and TMA which is mechanically made of maize grains nixtamalized *in situ* form the third group.

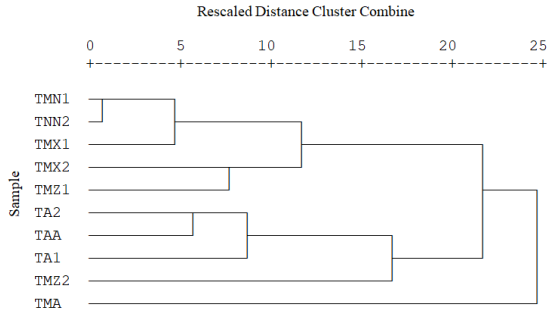

Fig.1. Dendrogram for cluster analysis of tortillas

Table 2. Tortillas groups sensory characteristics

Characteristic	Group	Minimum	Maximum	Mean	Standard deviation
Color uniformity	1	10.78	12.22	11.33[a]	0.72
	2	5.67	9.67	7.00[c]	1.81
	3	9.56	9.56	9.56[b]	-
Surface uniformity	1	8.00	11.78	9.84[a]	1.41
	2	6.56	11.78	8.36[c]	2.33
	3	9.00	9.00	9.00[b]	-
Moisture sensory	1	6.22	8.22	7.22[b]	0.92
	2	8.11	9.33	8.42[a]	0.61
	3	4.33	4.33	4.33[c]	-
Opacity sensory	1	7.67	9.22	8.53[c]	0.75
	2	6.00	11.89	9.69[b]	2.61
	3	12.78	12.78	12.78[a]	-
Maize smell	1	4.89	7.67	6.40[b]	1.13
	2	7.67	10.00	8.78[a]	0.96
	3	7.33	7.33	7.33[c]	-
Lime smell	1	5.78	9.89	8.24[a]	1.54
	2	3.56	7.89	4.83[c]	2.07
	3	5.44	5.44	5.44[b]	-
Fermented smell	1	3.00	4.56	3.80[b]	0.66
	2	2.11	3.67	2.86[a]	0.81
	3	2.89	2.89	2.89[a]	-
Acid taste	1	1.89	4.00	2.96[a]	0.86
	2	2.22	2.89	2.53[b]	0.31
	3	1.67	1.67	1.67[c]	-
Salted taste	1	2.44	3.44	3.02[a]	0.44
	2	2.78	3.67	3.28[a]	0.41
	3	2.67	2.67	2.67[b]	-
Sweet taste	1	1.67	4.00	3.09[b]	1.00
	2	3.78	5.44	4.67[a]	0.90
	3	2.89	2.89	2.89[c]	-
Lime taste	1	5.11	11.11	7.80[a]	2.39
	2	3.44	6.22	4.50[b]	1.24
	3	4.33	4.33	4.33[b]	-

Mean values followed by different letters are significantly different ($p < 0,05$).

Differences regarding tortillas samples characteristics between groups were observed (Tables 2, 3 and 4). According to the results obtained from the ANOVA, the variables of color uniformity, moisture sensory determined, maize smell, rolability, protein content and pH are significant ($p < 0.05$) in relation to the cluster membership, while the others are not ($p > 0.05$).

As it is shown in Table 2, tortillas from the first group have the most uniform color and surface, are the less opaque, have the lowest maize smell and the higher lime smell and taste and the highest fermented and acid taste compared to the other groups, probably due to the fact that they are made with machines

which may affect product quality. The second group of tortillas is made from maize grains nixtamalized *in situ* and is characterized by lower color and surface uniformity, higher moisture, maize smell, sweet and salted taste and lowest lime smell and taste, fermented smell and acid taste.

The last group formed by TMA tortilla from blue maize is characterized by lower moisture level, higher opacity, lower sweet and lime taste. The results are consistent with those obtained by Mendez-Albores et al. (2012) [17] for maize tortillas and by Hernández-Martínez et al. (2016) [9] for blue maize tortillas.

Regarding the texture (Table 3), the first group of tortillas has the highest elasticity and lower hardness measured by both subjective and objective methods.

Table 3.

Tortillas groups textural characteristics

Characteristic	Group	Minimum	Maximum	Mean	Standard deviation
Roughness	1	4.56	5.39	5.02[b]	0.32
	2	2.56	5.83	4.38[c]	1.40
	3	7.22	7.22	7.22[a]	-
Rolability	1	10.44	13.89	12.31[b]	1.30
	2	11.56	14.11	12.92[a]	1.11
	3	7.56	7.56	7.56[c]	-
Elasticity	1	5.78	7.06	6.54[a]	0.49
	2	5.00	7.89	5.97[c]	1.31
	3	4.78	4.78	4.78[b]	-
Hardness sensory	1	3.67	7.33	4.97[c]	1.59
	2	3.78	5.33	4.64[b]	0.81
	3	8.22	8.22	8.22[a]	-
Masticability	1	7.56	10.44	8.96[b]	1.31
	2	9.67	10.78	10.33[a]	0.54
	3	8.22	8.22	8.22[c]	-
Moisture absorption	1	8.20	11.11	9.66[b]	1.29
	2	8.89	11.11	9.67[b]	1.00
	3	11.11	11.11	11.11[a]	-
Tooth packing	1	6.00	8.78	7.44[b]	1.09
	2	6.78	9.44	7.89[a]	1.13
	3	4.44	4.44	4.44[c]	-
Firmness	1	2.86	4.64	3.75[c]	0.83
	2	3.71	6.94	4.87[a]	1.46
	3	4.61	4.61	4.61[b]	-

Mean values followed by different letters are significantly different ($p < 0,05$).

The chemical characteristics for the three groups are presented in Table 4.

Tortillas from the first group are characterized by the lowest protein, carbohydrates, polyphenols contents and antioxidant activity, while the FND, ash and water content are higher than of those from the other groups. Tortillas from the second group present the highest protein, FAD contents and antioxidant activity and lowest lipids content and pH. The third group is characterized by the highest lipids, carbohydrates and polyphenols levels and the lowest FND, FAD, ash and water contents. These results are in agreement with those reported by Valderrama-Bravo et al. (2017) and Hernandez-Martinez et al. (2016). The chemical characteristics of the final product are related to the maize variety, nixtamalization conditions (temperature, time, lime quantity) and production process (manual, mechanic) [18].

Table 4.

Tortillas groups chemical characteristics

Characteristic	Group	Minimum	Maximum	Mean	Standard deviation
Proteins	1	7.51	8.10	7.75^{b}	0.23
	2	8.05	9.52	9.07^{a}	0.68
	3	7.84	7.84	7.84^{b}	-
Lipids	1	1.03	1.44	1.19^{a}	0.15
	2	0.73	1.13	0.96^{b}	0.19
	3	1.23	1.23	1.23^{a}	-
Carbohydrates	1	32.44	41.07	36.90^{c}	3.60
	2	38.60	43.95	40.99^{b}	2.34
	3	43.02	43.02	43.02^{a}	-
FND	1	14.25	33.96	19.16^{a}	8.35
	2	8.32	27.01	18.55^{b}	8.14
	3	17.58	17.58	17.58^{c}	-
FAD	1	0.61	1.02	0.78^{b}	0.15
	2	0.54	1.83	1.20^{a}	0.54
	3	0.40	0.40	0.40^{c}	-
Ash	1	1.28	3.35	2.38^{a}	0.75
	2	1.41	2.14	1.66^{b}	0.32
	3	1.64	1.64	1.64^{b}	-
Water content	1	47.95	55.58	51.57^{a}	3.37
	2	43.72	51.00	47.31^{b}	3.04
	3	45.58	45.58	45.58^{c}	-
Poliphenols	1	0.17	0.38	0.25^{c}	0.08
	2	0.24	0.84	0.51^{b}	0.25
	3	0.65	0.65	0.65^{a}	-
IC_{50}	1	63.58	150.18	98.67^{a}	36.61
	2	54.00	108.48	79.91^{c}	22.94
	3	95.22	95.22	95.22^{b}	-
pH	1	8.70	11.08	10.27^{a}	0.93
	2	7.33	9.64	8.21^{c}	1.04
	3	8.76	8.76	8.76^{b}	-

Mean values followed by different letters are significantly different ($p < 0,05$).

Cluster analysis and groups characterization revealed that the artisanal tortillas and those made only of maize grains nixtamalized *in situ* have better characteristics than theindustrial ones which contain industrial maize flour.

4. Conclusion

Tortillas characteristics influence consumer's purchase decision and preferences, being important also for producers.

The industrialization tendency in the food processing field can affect the quality of the final product. The artisanal tortilla were found to have higher nutritional value compared to those made in tortillerias, raised values of proteins, fibers and poliphenols being identified.

Thus, the appearance of tortillerías where tortillas are mechanically made and the use of industrial maize flour instead of maize grains nixtamalized *in situ* is related to changes of product's quality. The studied tortillas marketed in Tlazala, Mexico studied can be grouped as function of their chemical, textural and sensory characteristics. The group with the best characteristics was made of mostly artisanal tortillas, all the comprising sample being made of 100% maize grain nixtamalized *in situ*. The main limitations of this study are related to the small area from which the samples were collected. Further research regarding the preferences of consumers and chemical particularities of tortillas from many regions of Mexico are needed to better complete the view of Mexican's consumer behavior.

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