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Analysis of the Impact of the Drying Process and the Effects of Corn Race on the Physicochemical Characteristics, Fingerprint, and Cognitive-Sensory Characteristics of Mexican Consumers of Artisanal Tostadas

Oliver Salas-Valdez [1], Emmanuel de Jesús Ramírez-Rivera [1,*], Adán Cabal-Prieto [2,*], Jesús Rodríguez-Miranda [3], José Manuel Juárez-Barrientos [4], Gregorio Hernández-Salinas [1,*], José Andrés Herrera-Corredor [5], Jesús Sebastián Rodríguez-Girón [6,7], Humberto Marín-Vega [1], Susana Isabel Castillo-Martínez [1], Jasiel Valdivia-Sánchez [8], Fernando Uribe-Cuauhtzihua [9] and Víctor Hugo Montané-Jiménez [2]

1 Tecnológico Nacional de México, Instituto Tecnológico Superior de Zongolica—Maestría en Ciencias en Desarrollo Regional y Tecnológico, Zongolica 95005, Veracruz, Mexico; 236w0855@zongolica.tecnm.mx (O.S.-V.); humberto_marin_pd177@zongolica.tecnm.mx (H.M.-V.); susana_castillo@zongolica.tecnm.mx (S.I.C.-M.)
2 Tecnológico Nacional de México, Instituto Tecnológico Superior de Huatusco, Av. 25 Poniente No. 100, Colonia Reserva Territorial, Huatusco 94106, Veracruz, Mexico; vmontanej@huatusco.tecnm.mx
3 Tecnológico Nacional de México, Instituto Tecnológico de Tuxtepec, Av. Dr. Víctor Bravo Ahuja No. 561, Colonia Predio el Paraíso, Tuxtepec 68350, Oaxaca, Mexico; jesus.rm@tuxtepec.tecnm.mx
4 Universidad del Papaloapan Campus Loma Bonita, Av. Ferrocarril S/N, Cd. Universitaria, Loma Bonita 68400, Oaxaca, Mexico; jmjuarez@unpa.edu.mx
5 Posgrado en Innovación Agroalimentaria Sustentable, Colegio de Postgraduados, Campus Córdoba, Km 348 Carretera Córdoba-Veracruz, Amatlán de los Reyes 94946, Veracruz, Mexico; jandreshc@colpos.mx
6 Secretaría de Ciencia, Humanidades, Tecnología e Innovación (SECIHTI), Estancias Posdoctorales por México, EPM 2024(1)—Departamento de Ciencias Básicas, División de Ciencias Básicas e Ingeniería (DCBI), Universidad Autónoma Metropolitana Unidad Azcapotzalco, Ciudad de México 02128, Mexico; jsrg@azc.uam.mx or sebasrg2993@gmail.com
7 Departamento de Energía, DCBI, Universidad Autónoma Metropolitana Unidad Azcapotzalco, Ciudad de México 02128, Mexico
8 Tecnológico Nacional de México, Instituto Tecnológico Superior de Zongolica—Ingeniería en Innovación Agrícola Sustentable, Zongolica 95005, Veracruz, Mexico; jasiel_iias@zongolica.tecnm.mx
9 Tecnológico Nacional de México, Instituto Tecnológico Superior de Zongolica—Ingeniería en Gestión Empresarial, Zongolica 95005, Veracruz, Mexico; fernando_uribe@zongolica.tecnm.mx
* Correspondence: ejramirezrivera@zongolica.tecnm.mx (E.d.J.R.-R.); acabalp@huatusco.tecnm.mx (A.C.-P.); gregorio_hs@zongolica.tecnm.mx (G.H.-S.)

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Abstract

The objective of this study was to analyze the impact of solar and hybrid dryers on the physicochemical characteristics, fingerprints, and cognitive-sensory perceptions of Mexican consumers of traditional tostadas made with corn of different races. Corn tostadas from different native races were evaluated with solar and hybrid (solar-photovoltaic solar panels) dehydration methods. Proximal chemical quantification, instrumental analysis (color, texture), fingerprint by Fourier transform infrared spectroscopy (FTIR), and sensory-cognitive profile (emotions and memories) and its relationship with the level of pleasure were carried out. The data were evaluated using analysis of variance models, Cochran Q, and an external preference map (PREFMAP). The results showed that the drying method and corn race significantly ($p < 0.05$) affected only moisture content, lipids, carbohydrates, and water activity. Instrumental color was influenced by the corn race effect, and the dehydration type influenced the fracturability effect. FTIR fingerprinting results revealed that hybrid samples exhibited higher intensities, particularly associated with higher lime concentrations, indicating a greater exposure of glycosidic or protein structures. Race and

dehydration type effects impacted the intensity of sensory attributes, emotions, and memories. PREFMAP vector model results revealed that consumers preferred tostadas from the Solar-Chiquito, Hybrid-Pepitilla, Hybrid-Cónico, and Hybrid-Chiquito races for their higher protein content, moisture, high fracturability, crunchiness, porousness, sweetness, doughy flavor, corn flavor, and burnt flavor, while images of these tostadas evoked positive emotions (tame, adventurous, free). In contrast, the Solar-Pepitilla tostada had a lower preference because it was perceived as sour and lime-flavored, and its tostada images evoked more negative emotions and memories (worried, accident, hurt, pain, wild) and fewer positive cognitive aspects (joyful, warm, rainy weather, summer, and interested). However, the tostadas of the Solar-Cónico race were the ones that were most rejected due to their high hardness and yellow to blue tones and for evoking negative emotions (nostalgic and bored).

Keywords: nutritional quality; sensory attributes; recall of emotions and memories; PREFMAP vector model; preference reactions; hybrid; solar dehydrator

1. Introduction

Corn (*Zea mays* L.) represents one of the cereals of greatest social, economic, and industrial importance [1]. In Mexico, there are 59 native corn races that have been assigned more than 700 traditional culinary uses, such as tortillas, tostadas, among others [2]. The tortilla is considered a traditional food for daily consumption, and its per capita consumption rates are 79.5 kg and 56.7 kg for rural and urban areas, respectively [3,4]. Currently, multiple investigations have been carried out on the effects of grain color, race type, traditional practices, and sociodemographic variables on bioactive compounds and nutritional, textural, physicochemical, cognitive, and sensory aspects in artisanal and commercial corn-based tortillas [4–9]. However, from the tortilla, various base products can be elaborated such as totopos, tortilla strips, and mainly tostadas, which are used in Mexican gastronomy for the preparation of different dishes (e.g., enchiladas, chilaquiles, tortilla soup, pozole, among others). Essentially, the Mexican tostada is a tortilla that undergoes a frying or baking process that gives it unique characteristics such as rigidity and crispness. It can be consumed with or without other foods such as cheese, salsa, and fish, among others [10]. Artisan tostadas are highly demanded and appreciated, and in turn become an alternative source of income for producers who distribute this food in different markets [11], thus contributing to the activation of the local, regional, and national economies. Currently, some of the research on tostadas made from maize tortillas has focused on the analysis of fortification with algae flour and its impact on chemical, microbiological, and sensory aspects, as well as the production system of this food [12,13]. However, the analysis of the type of dehydration and the variety of corn used for the production of Mexican tostadas has not been thoroughly explored. In this sense, dehydration is an important factor in the elaboration of tostadas, as it provides the typical sensory characteristics of the product and additionally allows for an extended shelf life until the moment of consumption [14]. However, dehydration can also have either a positive or negative impact on various quality parameters of tostadas such as physicochemical and instrumental aspects, among others [14,15]. Currently, there is a wide variety of dehydration methods (e.g., oven drying, microwave drying, among others) available on the market, but they have shown certain disadvantages, such as high energy consumption, which contributes to increased production costs for artisan tostada producers [16]. Faced with this situation, sustainable and profitable dehydration alternatives have been chosen

that use removable solar energy technologies [17]. For example, solar dehydrators (e.g., combining solar energy with conventional energy) have been developed for foods such as onion [18], potato [19], and banana [20], but they have not been explored in artisanal tostadas made with corn of different races. The aforementioned type of dehydration contributes to energy efficiency and mitigates the generation of greenhouse gases (e.g., carbon dioxide and monoxide, among others) derived from the combustion of fossil fuels and/or the use of biomass such as firewood for energy production [21]. For example, in Mexico, firewood is one of the most important sources of energy, contributing 2.8% of the total primary energy production, and is widely used intensively for cooking in the states of Campeche, Chiapas, Guerrero, Hidalgo, Michoacan, Oaxaca, Puebla, San Luis Potosi, Tabasco, Veracruz and Yucatan [22]. Therefore, the objective of this research was to analyze the impact of the hybrid indirect solar dryer and the effect of corn race on the physicochemical characteristics, fingerprint, and sensory-cognitive response of Mexican consumers of artisanal tostadas.

2. Materials and Methods

2.1. Solar and Hybrid Dehydration Equipment

The solar dryer used in this research is made of xochicuahuitl (*Cordia alliodora*) wood and is equipped with the following accessories: an inclined acrylic solar collector and a drying chamber with internal trays (Figure 1A). The hybrid dryer consists of the same solar dryer, but with a generic brand 500-watt photovoltaic solar panel on top and three 40-watt Philips® incandescent lamps for additional heat input, allowing it to operate with both solar and conventional energy (Figure 1B). This combination of elements allows the tostadas to be dried sustainably, efficiently taking advantage of solar energy.

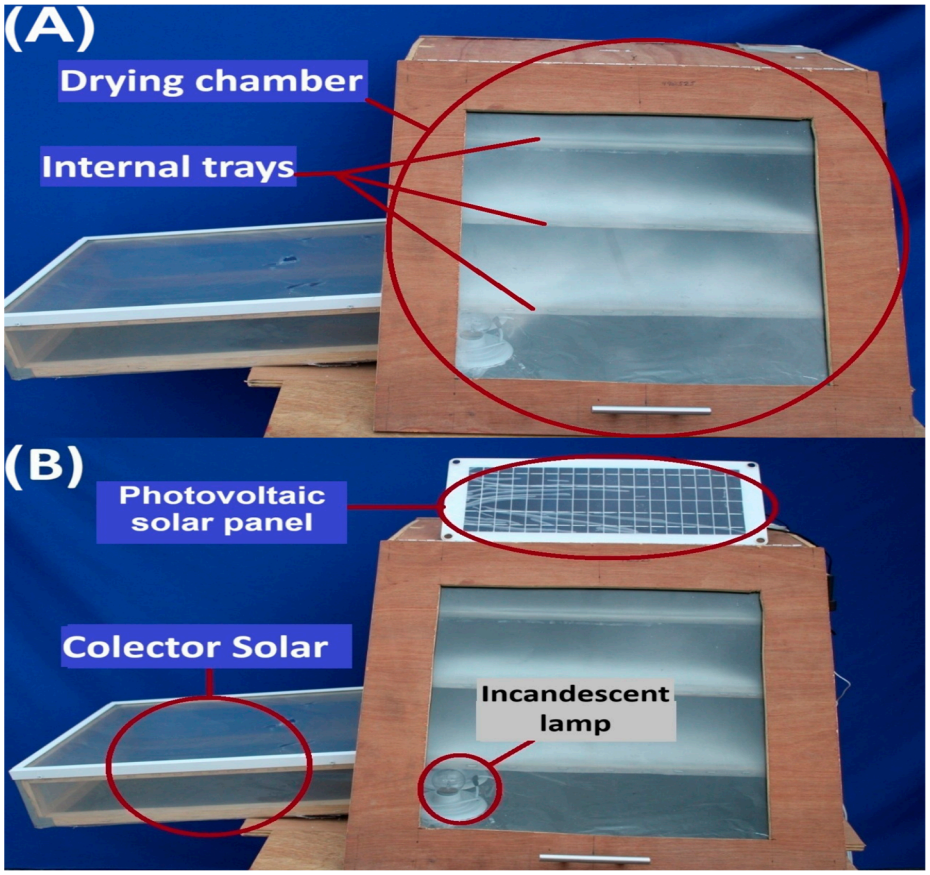


Figure 1. Design of the dehydrator for drying tostadas. (**A**) Solar dehydrator; (**B**) Hybrid dehydrator.

2.2. Manufacturing of Tostadas

Tostadas were produced in the following steps: (1) origin and selection of the corn races; (2) nixtamalization; (3) tortilla production; (4) tortilla dehydration. In step 1, corn kernels of three races were acquired—Chiquito, Pepitilla, and Cónico—from the municipalities of Rafael Delgado, Texhuacán, and Xoxocotla, respectively, all located in the state of Veracruz, Mexico (Table 1).

Table 1. Native corn races used to make the tostadas.

Race	Municipality	Locality	Altitude	Soil Type	Climate Type	Annual Precipitation
Chiquito	Rafael Delgado	Las Sirenas	1163	Chromic Luvisol	(A)C(m)	1500–2000
Pepitilla	Texhuacán	El Mirador	2067	Chromic Luvisol	C(m) (f)	1200–1500
Cónico	Xoxocotla	Xoxocotla	2115	Chromic Luvisol	C(m) (f)	1200–500

Step 2. For this stage, nixtamalization was carried out, which consisted of preparing a solution of water with calcium hydroxide (lime) in a proportion of 1 g of lime for every 100 g of corn (equivalent to 10 g of lime per kilogram of corn), and using approximately 2.5 to 3 L of water per kilogram of corn. The mixture was then heated for 20 min at 90 °C. When that time was up, it was removed from the heat to let it rest for 12 h at room temperature (25 ± 5 °C). After that, two to three manual washes were made with clean water to eliminate excess lime and remove the loosened pericarp. Finally, the corn grain was ground in a commercial mill until fresh dough was obtained. Step 3. To make the tortillas, dough balls weighing 30 g were formed, and then dough discs 15 cm in diameter and 2 mm thick were made using a manual machine [23]. Subsequently, the discs were cooked on a hot plate called a metal "comal" at 220 °C for an average time of 3 min and then left to cool for 30 min. They were packed in paper and polyethylene bags and transported to the place where the tostadas were made. Step 4. The tortillas underwent a hybrid solar dehydration process. Solar dehydration consisted of placing the tortillas on food-grade stainless steel mesh trays, randomly distributing them by race to ensure even toasting across all samples. All tortillas were labeled. The internal temperature of the solar dehydrator ranged between 40 and 46 °C with an average relative humidity of 42.07% during a drying time of 6 to 8 h. In the hybrid dehydrator, powered by a photovoltaic panel, the average temperature remained stable at 48 °C with an average relative humidity of 47.86%, and the drying time was maintained between 6 and 8 h.

The experimental design used was completely randomized, in which the commercial tortilla was used as a control, where samples were dehydrated by both methods for a total of 8 treatments (n = 4 samples dehydrated by solar [1 commercial tostada and 3 made with native corn] and n = 4 samples dehydrated with incandescent lamps [1 commercial tostada and 3 made with native corn]). After obtaining the tostadas, they were allowed to cool for a period of 5 minutes at room temperature (25 ± 5 °C), and finally they were sealed in bags using a hand-press sealing machine (brand IONIX, SY-200, Zhejiang, made in China).

2.3. Proximate Chemical Determination and Water Activity of Artisanal Tostadas

Proximate chemical parameters were determined according to the Association of Official Analytical Chemists (A.O.A.C). Protein contents (method 978.02) were obtained using a Büchi SpeedDigester K-439 system, Büchi Labortechnik AG, Flawil, Suiza. Lipids (method 960.39) were obtained using a Büchi E-812 system. Ash (method 940.05) and carbohydrates (method 978.10) were also obtained by this system. Moisture content (method 925.04) was obtained using an OHAUS model MB23 moisture analyzer. Water activity (a_w) was analyzed using a Pawkit portable device (Decagon Devices, Inc. Pullman, WA, USA).

2.4. Instrumental Determination of Color and Texture in Artisanal Tostadas

Color parameters L (lightness), a* (red-green), b* (yellow-blue), chroma, and hue angle were determined using an UltraScan™ Vis colorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA). The tostadas were analyzed in triplicate from three different surface areas. The tostadas fracture was determined by puncture and compression using a TA-XT plus texture tester (Stable Microsystems, Haslemere, Surrey, UK). A 75 mm P/75 plate was used for puncture and compression. The operating conditions of the equipment were a 10 cm distance between samples at a speed of 40 mm/s. Fracture tests were performed on a total of nine replicates.

2.5. Fingerprint by FTIR: Analysis for Functional Groups Identification

To identify the functional groups, a Bruker Alpha-2 FTIR spectrophotometer equipped with an Eco-ATR sampling module for liquids and solids (single-reflection ATR with ZnSe and Ge crystals) was employed. Tostada samples were analyzed in the 4000–500 cm^{-1} range with a resolution of 2 cm^{-1}. A total of 64 scans were collected at room temperature. Before the analysis, the tostada samples were milled in an agate mortar, the resultant powder being collected and dried at 80 °C for 24 h in an oven.

2.6. Sensory Profile of Artisanal Tostadas and Liking

A panel of 100 consumers was formed with students from the Tecnológico Nacional de México Campus Huatusco, of which 58% were women and 42% were men, with an age range of 18–24. Consumers were selected according to [24,25]. Each consumer was interviewed to determine their availability, motivation, and non-aversion to corn and by-products [24,25]. Consumers used the Rate-All-That-Apply (RATA) technique [26] to evaluate tostadas based on sensory attributes: Crunchy, Corn-F, Sweet-BT, Salty-BT, Lime-F, Burnt-F, Hard, Porous, Dough-F, and Sour-BT. Consumers used a 9-point scale (low and high intensity), as it improves discrimination [27]. Consumers then used a 9-point hedonic scale, where 1 = extremely dislike and 9 = very like to determine their level of enjoyment of each sample evaluated [28]. In both tests, samples were randomized and served in a monadic sequential manner according to a Latin square experimental design [29], and a 10-min break was given between each sample evaluation so that each consumer could eliminate residues from the previous sample using water and white bread. The statistical power of the test was 0.99 for a moderate effect size (d = 0.80, n = 100, d = 0.80, sig.level = 0.05) [30].

2.7. Cognitive Profile Based on Online Survey

A survey was designed using Google Forms that consisted of the following sections: (1) consumer type; (2) frequency of tostada consumption; (3) evocation of emotions; and (4) evocation of memories. Consumers used the Check-All-That-Apply (CATA) technique to select the emotions [31] and memories [32] that each tostada image evoked. The tostada images (24.1 megapixel resolution) were used as shown in Figure 2. The tostada images were acquired using a Canon INC. Melville, NY, USA, model Eos Rebel T7, with fixed lighting [33]. The images were randomized for each consumer [34], and the survey was answered by a total of 505 consumers from different geographical points in Mexico (Veracruz, Durango, Baja California, Guerrero, Ciudad de Mexico, Oaxaca, Puebla, Estado de Mexico, Tamaulipas, Quintana Roo, Nuevo Leon, Tabasco, Chihuahua, Sinaloa, Tlaxcala, Queretaro) where 52.7% were women and 47.3% men with different ages: 18–30 (85.5%), 31–43 (8.5%), 44–55 (4.8%), 56–75 (1%).

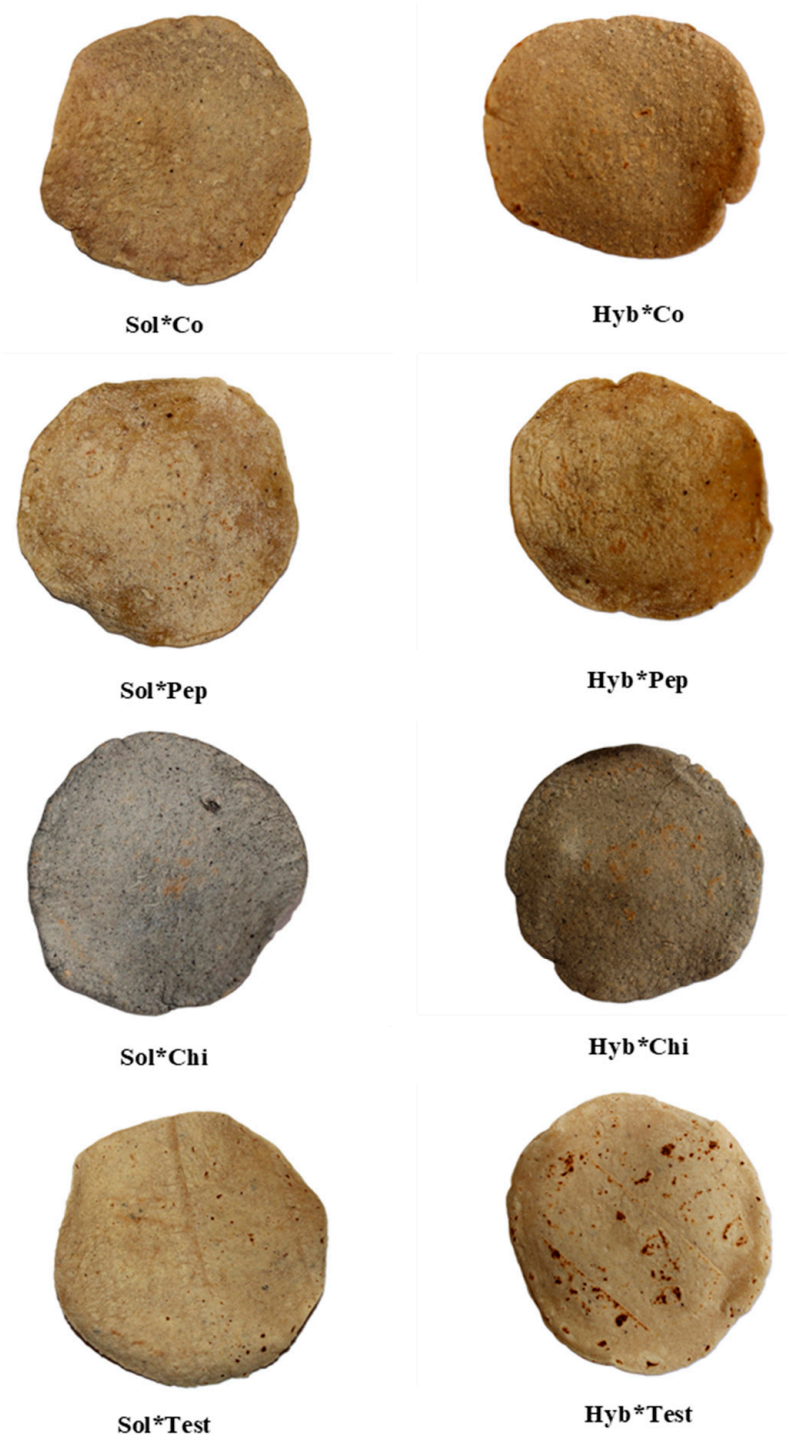


Figure 2. Images of tostadas evaluated using solar and hybrid methods. Hyb*Co = Hybrid dehydrated Cónico corn tostada; Hyb*Chi = Hybrid dehydrated Chiquito corn tostada; Hyb*Pep = Hybrid dehydrated Pepitilla corn tostada; Hyb*Test = Hybrid dehydrated commercial corn tostada; Sol*Co = Solar-dehydrated Cónico corn tostada; Sol*Chi = Solar-dehydrated Chiquito corn tostada; Sol*Pep = Solar-dehydrated Pepitilla corn tostada; Sol*Test = Solar-dehydrated commercial corn tostada.

The total number of consumers who responded to the survey for this research was higher than those used in research by [35–37], who developed online sensory evaluations due to health restrictions caused by the COVID-19 pandemic. The statistical power of the test was 1.00 for a moderate effect size (d = 0.80, n = 505, d = 0.80, sig.level = 0.05 [29]. Calculation was performed using the pwr function implemented in R version 3.2.5 programming

language R Core Team, 2019 [38]. The statistical treatment consisted of applying Cochran's Q statistical technique to determine significant emotions and memories and subsequently construct a cognitive map using correspondence analysis (CA), where the tostadas and the type of emotion and memory they evoke in consumers are shown [39].

2.8. Statistical Analysis

2.8.1. Chemical and Instrumental Determination

The results of the chemical determinations (proteins, lipids, ash, moisture, and water activity) and instrumental determinations (color and texture) were evaluated using a two-factor analysis of variance (ANOVA) model (corn race and dehydration method) with interaction (race*method) and LSD to detect significant differences with $\alpha = 5\%$.

2.8.2. Identification of Significant Sensory Attributes, Emotions and Memories

The sensory attribute data were collected in a matrix of dimensions ($J * I$) K, where $J = 8$ tostadas, $I = 100$ consumers, and $K = 10$ sensory attributes, which were analyzed using a two-factor ANOVA model (race-dehydration method and consumer) and LSD to detect significant differences with $\alpha = 5\%$. Subsequently, the sensory profile of the tostadas was generated and represented through principal component analysis, and the discrimination among samples was evaluated using 95% confidence ellipses for each product, based on 500 resamples [28]. Emotions and memories data were collected in a ($J * I$) K-dimensional matrix, where $J = 8$ tostadas images, $I = 505$ consumers, and $K = 50$ cognitive words ($n = 25$ emotions and $n = 25$ memories). The cognitive profile data were analyzed using Cochran's Q to identify the significant emotions and memories evoked by the tostada images [39].

2.8.3. Level of Liking Based on Significant Attributes, Emotions, and Memories

An External Preference Map (PREFMAP) was developed according to [28] with the objective of determining the causes of consumer preference or rejection based on significant chemical, instrumental, and sensory attributes, as well as emotions and memories ($p < 0.05$). As a first step, consumer classes were made using the ascending hierarchical classification (AHC) technique (Ward's method). Subsequently, consumer classes (Y) were related to sensory attributes, emotions, and significant memories (X) according to the following model:

$$\text{Vector model: } Y_i = \alpha + \beta_{1\times1} + b_{2\times2} + \varepsilon$$

where: X are the data of chemical, instrumental, and sensory attributes, plus emotions and memories ($p < 0.05$), Y are the preference data, which are the coordinates of a sample of tostada in the first and second principal components, Y_i is the hedonic value of a consumer assigned to a class α, β_1 are the coefficients of the model, and ε is the error term of the model [28].

Cochran's Q, ANOVA, and PREFMAP were performed with the software XLSTAT software, version 2020 [40] (Addinsoft, New York, NY, USA). Confidence ellipses were generated with SensoMineR software version 3.2.5 [41] implemented in R version 3.2.5 programming language [38].

3. Results and Discussion

3.1. Chemical and Instrumental Determination

Table 2 shows the probability values for the chemical and instrumental determinations. It was observed that the race effect influenced all determinations except for ash, protein, and texture contents. In the case of the dehydration method factor, it was found to have an influence on all determinations except for protein content and texture. However, the

race*method interaction only had an effect on moisture, protein, carbohydrates, a_w, L, b*, and fracturability contents.

Table 2. Probability results of the factors race and dehydration method with interaction.

Determination	Race	Method	Race*Method
Moisture	<0.0001	<0.0001	<0.0001
Lipid	<0.0001	0.009	0.211
Ash	0.301	<0.0001	0.119
Protein	0.329	0.301	0.020
Carbohydrates	<0.0001	<0.0001	<0.0001
a_w	<0.0001	<0.0001	<0.0001
L	<0.0001	0.218	<0.0001
a*	<0.0001	0.965	0.308
b*	<0.0001	0.027	0.032
Chroma	<0.0001	0.059	0.147
Hue Angle	<0.0001	0.961	0.181
Fracturability	0.288	<0.0001	0.040
Texture	0.078	0.361	0.501

L = Luminosity, a* = Red-Green, b* = Yellow-Blue. Race*Method = Race by method interaction.

Table 3 shows the average values for each chemical determination. It was observed that for the race factor, the highest moisture content ($p < 0.05$) was found for the tostada made with Chiquito corn (8.00 ± 0.143) followed by Cónico (7.42 ± 0.143), Pepitilla (6.52 ± 0.143), and control (5.73 ± 0.143). These differences in humidity may be due to the water retention capacity of the different masses of corn of each race since, during the drying of the flour, the starch chains are degraded into shorter chains that retain a higher water content [8]. In the case of lipids, the highest content was found in tostadas made with Cónico corn breed (1.73 ± 0.103) followed by Chiquito tostadas (1.22 ± 0.103) and tostadas made with Pepitilla corn (0.86 ± 0.103), which had a lipid content similar ($p > 0.05$) to the control (0.63 ± 0.103). According to [42], lipid differences may be due to the loss of pericarp during nixtamalization. In contrast, no differences ($p > 0.05$) were observed in the protein content of tostadas made with dough from different corn races. However, the highest carbohydrate content ($p < 0.05$) was obtained for the control sample (88.81 ± 0.347), although tostadas made with dough from different corn races were similar ($p > 0.05$), with values of 87.71 ± 0.34, 85.11 ± 0.347, and 85.40 ± 0.347 for Pepitilla, Chiquito, and Cónico, respectively. One of the possible causes of this result is that the carbohydrate part of the masses of these races of corn are contained in amylose–lipid complexes, making them more resistant to enzymatic attack and to relatively high temperatures between 90–130 °C [43]. Ref. [42] evaluated samples of tortilla chips made with corn dough from different races (Zapalote, Tuxpeño, Chalqueño, San Blas, and Tehuantepec) grown in the state of Oaxaca, Mexico, and observed ranges of lipid, ash, and carbohydrate contents of 2.7–4.1%, 1.05–1.75%, and 88.6–86.9%, respectively. For their part, Ref. [12] evaluated functional tostadas made with corn (*Z. mays*) and seaweed (*Ulva clathrata*) and reported moisture, lipid, ash, and carbohydrate contents of 8.96, 1.16, 1.37, and 76.4%, respectively. For a_w, the control sample obtained the highest content (0.69 ± 0.002) compared to the tostadas made from corn of the Pepitilla (0.66 ± 0.002), Chiquito (0.64 ± 0.002), and Cónico (0.67 ± 0.002) races. Ref. [44] reported values of a_w 0.43 to 0.84 in corn chips after frying and noted that, as moisture was gradually lost, the integral entropy of the product decreased to a minimum, generating less availability of water molecules for decomposition reactions. For the dehydration method factor, it was found that the moisture (7.72 ± 0.101), lipid (1.26 ± 0.073), and ash (1.67 ± 0.108) contents were higher ($p < 0.05$) compared to the tostadas obtained by the solar method (6.10 ± 0.101, 0.96 ± 0.073, and 1.00 ± 0.108 for moisture, lipid, and ash, respec-

tively). However, the highest carbohydrate contents and a_w ($p < 0.05$) were obtained by the solar method (88.20 ± 0.245; 0.69 ± 0.002) compared to the hybrid method (85.31 ± 0.245; 0.65 ± 0.002). The results obtained are similar to those reported in different investigations, such as those carried out by [45], who evaluated the effect of drying prior to frying in toasted tortillas and reported moisture contents between 2.07 and 6.5% and lipids between 8–36 and 9.01%, the latter parameter being higher than that obtained in the tostadas in our research. For their part, Ref. [46] designed a solar dryer for fruits and vegetables, achieving humidity percentages of 15 to 16%. According to [47,48], solar dehydration causes important changes in the biological, physical, and chemical compositions of the food matrix, which may be related to low moisture, lipid, and ash contents. Regarding the interaction race*method (Table 3), it was found that this interaction influenced all the determinations analyzed, with the exception of lipid and ash content. For example, the highest moisture content ($p < 0.05$) was found for Hyb*Chi (10.32 ± 0.202), followed by the samples Hyb*Co (8.56 ± 0.202) and Sol*Pep (7.2 ± 0.202), while the samples Sol*Co, Hyb*Test, Sol*Chi and Hyb*Pep had similar contents ($p > 0.05$), and, finally, the sample Sol*Test (5.28 ± 0.202). The highest level of protein content was found in the samples Hyb*Co (4.66 ± 0.386), Hyb*Chi (4.66 ± 0.386), Sol*Chi (3.79 ± 0.386), Sol*Pep (4.37 ± 0.386), and Sol*Test (3.50 ± 0.386); the samples Hyb*Test (3.50 ± 0.386), Hyb*Pep (3.20 ± 0.386), and Sol*Co (3.20 ± 0.386) presented similar protein percentages ($p > 0.05$). The highest carbohydrate content ($p < 0.05$) was obtained for the Sol*Test sample (89.99 ± 0.49), while the following samples Hyb*Pep, Hyb*Test, Sol*Co, Sol*Chi, and Sol*Pep samples were similar ($p > 0.05$); the Hyb*Co and Hyb*Chi samples also presented similar contents ($p > 0.05$). For a_w, the Hyb*Chi sample obtained the highest content (0.60 ± 0.004), followed by Hyb*Pep (0.61 ± 0.004), Sol*Co (0.65 ± 0.004), and Sol*Chi (0.69 ± 0.004); Hyb*Co, Pepitilla by the Sol*Pep and Sol*Test were similar ($p > 0.05$).

Table 4 shows the results of the instrumental determinations. It is shown that, for the race factor, the control tostada was significantly brighter (71.48 ± 1.47) compared to the tostadas made with corn of different races. In the case of the parameter a*, only positive values were obtained, indicating that the tostada samples analyzed had a red hue. In this case, the tostada made with Cónico race corn was the one that showed the highest value ($p < 0.05$) compared to the rest of the tostada samples. This result indicates that the tostadas presented red hues. For the variable b*, only positive values were found, indicating that the tostadas presented some yellow hues. Therefore, the tostadas made with Cónico (21.44 ± 0.71), Pepitilla (21.45 ± 0.71), and control (20.21 ± 0.71) corn varieties showed the highest value ($p < 0.05$) compared to the sample made with Chiquito (8.01 ± 0.71). However, the tostada samples with the highest overall color intensity (chroma) were those made with Pepitilla (22.06 ± 0.73), Cónico (21.95 ± 0.73), and control (20.32 ± 0.73) corn, and the tostadas made with Chiquito corn showed the lowest color intensity (8.22 ± 0.73). Regarding the hue angle, it could be observed that the tostadas were located in the region of yellow and orange tones (located between 60–90°), where the tostadas made with Pepitilla corn and the control had a lighter yellow color compared to the rest of the tostadas, which presented light orange colors. No significant differences were found between tostada samples for the fracture and texture variables. For the dehydration method factor, a significant effect ($p < 0.05$) was only found for fracturability, in which the most brittle tostadas were produced with the hybrid method (2.42 ± 0.12) compared to the solar method (1.57 ± 0.12). In the case of the interaction (race*method), it was observed that the samples Sol*Test (70.14 ± 0.57) and Hyb*Test (72.83 ± 2.09) were those that obtained a higher luminosity ($p < 0.05$), while the tostadas made with Cónico race corn with mixed dehydration presented similar values ($p > 0.05$) of luminosity; although, for the rest, the Chiquito and Pepitilla tostadas by the solar method were brighter than

the tostadas made with the same races of corn, but by the hybrid method. Only positive values were obtained for the a* variable, indicating that the tostada samples exhibited reddish hues. However, for the parameter b*, positive values were obtained (yellow tones), among which the Hyb*Chi (9.61 ± 1.00) and Sol*Chi (6.40 ± 1.00) tostadas were the lowest compared ($p < 0.05$) to the rest of the tostada samples, which showed similar values ($p > 0.05$) between 19.19 and 22.55. In terms of color saturation (chroma) and hue angle, all tostada samples exhibited strong yellow intensities. In the case of fracturability, it was found that the interaction of both effects (race and dehydration method) influenced this parameter, since it was observed that Hyb*Co, Hyb*Chi, and Hyb*Pep tostadas presented greater resistance to fracture (2.58 ± 0.22, 1.90 ± 0.24, and 2.19 ± 0.24 N, respectively) compared to their counterparts dehydrated by the solar method (1.29 ± 0.24, 1.68 ± 0.24, and 1.74 ± 0.24 N, respectively). This tendency was also found for the control tostadas, in which the Hyb*Test sample showed a greater resistance (2.99 ± 0.24 N) compared to the Sol*Test sample (1.56 ± 0.24 N).

Table 3. Average values and standard error of chemical determinations.

Factor: Race						
	Moisture	**Lipid**	**Ash**	**Protein**	**Carbohydrate**	**a_w**
Cónico	7.42 ± 0.143 b	1.73 ± 0.103 a	1.49 ± 0.153 a	3.93 ± 0.073 a	85.40 ± 0.347 c	0.67 ± 0.002 c
Chiquito	8.00 ± 0.143 a	1.22 ± 0.103 b	1.43 ± 0.153 a	4.23 ± 0.073 a	85.11 ± 0.347 c	0.64 ± 0.002 a
Pepitilla	6.52 ± 0.143 c	0.86 ± 0.103 c	1.09 ± 0.153 a	3.79 ± 0.073 a	87.71 ± 0.347 b	0.66 ± 0.002 b
Commercial (Control)	5.73 ± 0.143 d	0.63 ± 0.103 c	1.31 ± 0.153 a	3.50 ± 0.073 a	88.81 ± 0.347 a	0.69 ± 0.002 d
Factor: Dehydration Method						
	Moisture	**Lipid**	**Ash**	**Protein**	**Carbohydrate**	**a_w**
Hybrid	7.72 ± 0.101 a	1.26 ± 0.073 a	1.675 ± 0.108 a	4.01 ± 0.193 a	85.31 ± 0.245 b	0.65 ± 0.002 a
Solar	6.10 ± 0.101 b	0.96 ± 0.073 b	1.00 ± 0.108 b	3.72 ± 0.193 a	88.20 ± 0.245 a	0.69 ± 0.002 b
Interaction: Race-Dehydration Method						
	Moisture	**Lipid**	**Ash**	**Protein**	**Carbohydrate**	**a_w**
Hyb*Co	8.56 ± 0.202 b	2.02 ± 0.146 a	1.93 ± 0.216 a	4.66 ± 0.386 a	82.81 ± 0.49 c	0.70 ± 0.004 ef
Hyb*Chi	10.32 ± 0.202 a	1.19 ± 0.146 a	1.43 ± 0.216 a	4.66 ± 0.386 a	82.37 ± 0.49 c	0.60 ± 0.004 a
Hyb*Pep	5.85 ± 0.202 de	0.99 ± 0.146 a	1.49 ± 0.216 a	3.20 ± 0.386 c	88.44 ± 0.49 b	0.61 ± 0.004 b
Hyb*Test	6.17 ± 0.202 d	0.84 ± 0.146 a	1.83 ± 0.216 a	3.50 ± 0.386 bc	87.63 ± 0.49 b	0.68 ± 0.004 d
Sol*Co	6.28 ± 0.202 d	1.45 ± 0.146 a	1.06 ± 0.216 a	3.20 ± 0.386 c	87.99 ± 0.49 b	0.65 ± 0.004 c
Sol*Chi	5.67 ± 0.202 de	1.24 ± 0.146 a	1.43 ± 0.216 a	3.79 ± 0.386 abc	87.84 ± 0.49 b	0.69 ± 0.004 e
Sol*Pep	7.2 ± 0.202 c	0.72 ± 0.146 a	0.70 ± 0.216 a	4.37 ± 0.386 ab	86.99 ± 0.49 b	0.70 ± 0.004 f g
Sol*Test	5.28 ± 0.202 e	0.42 ± 0.146 a	0.79 ± 0.216 a	3.50 ± 0.386 bc	89.99 ± 0.49 a	0.71 ± 0.004 g

± = Standard error; Different letters in the column and by factor indicate significant differences ($p < 0.05$); Hyb*Co = Hybrid dehydrated Cónico corn tostada; Hyb*Chi = Hybrid dehydrated Chiquito corn tostada; Hyb*Pep = Hybrid dehydrated Pepitilla corn tostada; Hyb*Test = Hybrid dehydrated commercial corn tostada; Sol*Co = Solar-dehydrated Cónico corn tostada; Sol*Chi = Solar-dehydrated Chiquito corn tostada; Sol*Pep = Solar-dehydrated Pepitilla corn tostada; Sol*Test = Solar-dehydrated commercial corn tostada.

Table 4. Average values and standard error of instrumental determinations.

Factor: Race							
	L	**a***	**b***	**Chroma**	**Hue Angle**	**Fracture (N)**	**Texture**
Cónico	40.11 ± 1.47 b	4.81 ± 0.40 b	21.44 ± 0.71 b	21.95 ± 0.73 b	78.60 ± 1.01 a	1.94 ± 0.17 a	1.31 ± 0.13 a
Chiquito	35.21 ± 1.47 a	1.78 ± 0.40 a	8.01 ± 0.71 a	8.22 ± 0.73 a	78.01 ± 1.01 a	1.79 ± 0.17 a	1.39 ± 0.13 a
Pepitilla	39.15 ± 1.47 ab	2.15 ± 0.40 a	21.45 ± 0.71 b	22.06 ± 0.73 b	85.08 ± 1.01 b	1.97 ± 0.17 a	1.45 ± 0.13 a
Commercial (Control)	71.48 ± 1.47 c	1.92 ± 0.40 a	20.21 ± 0.71 b	20.32 ± 0.73 b	84.58 ± 1.01 b	2.28 ± 0.17 a	0.98 ± 0.13 a
Factor: Dehydration Method							
	L	**a***	**b***	**Chroma**	**Hue Angle**	**Fracture (N)**	**Texture**
Hybrid	45.54 ± 1.04 a	2.67 ± 0.28 a	18.64 ± 0.50 b	18.89 ± 0.52 a	81.54 ± 0.71 a	2.42 ± 0.12 b	1.34 ± 0.9 a
Solar	47.43 ± 1.04 a	2.65 ± 0.28 a	16.91 ± 0.50 a	17.38 ± 0.52 a	81.59 ± 0.71 a	1.57 ± 0.12 a	1.22 ± 0.9 a
Interaction: Race-Dehydration Method							
	L	**a***	**b***	**Chroma**	**Hue Angle**	**Fracture (N)**	**Texture**
Hyb*Co	44.72 ± 2.09 d	4.68 ± 0.57 a	22.55 ± 1.00 d	23.04 ± 1.04 a	78.37 ± 1.43 a	2.58 ± 0.22 c d	1.55 ± 0.19 a
Hyb*Chi	27.550 ± 2.08 a	2.39 ± 0.57 a	9.61 ± 1.00 b	9.93 ± 1.04 a	76.28 ± 1.43 a	1.90 ± 0.24 a b c	1.43 ± 0.19 a
Hyb*Pep	37.06 ± 2.09 bc	2.21 ± 0.57 a	21.18 ± 1.00 cd	21.30 ± 1.04 a	85.36 ± 1.43 a	2.19 ± 0.24 b c	1.47 ± 0.19 a
Hyb*Test	72.83 ± 2.09 e	1.41 ± 0.57 a	21.24 ± 1.00 cd	21.28 ± 1.04 a	86.17 ± 1.43 a	2.99 ± 0.24 d	0.93 ± 0.19 a
Sol*Co	35.50 ± 2.09 b	4.94 ± 0.57 a	20.33 ± 1.00 cd	20.85 ± 1.04 a	78.84 ± 1.43 a	1.29 ± 0.24 a	1.08 ± 0.19 a
Sol*Chi	42.87 ± c d	1.17 ± 0.57 a	6.40 ± 1.00 a	6.51 ± 1.04 a	79.74 ± 1.43 a	1.68 ± 0.24 ab	1.35 ± 0.19 a
Sol*Pep	41.23 b c d	2.08 ± 0.57 a	21.72 ± 1.00 cd	22.82 ± 1.04 a	84.81 ± 1.43 a	1.74 ± 0.24 ab	1.43 ± 0.19 a
Sol*Test	70.14 ± 0.57 e	2.43 ± 0.57 a	19.19 ± 1.00 c	19.35 ± 1.04 a	82.99 ± 1.43 a	1.56 ± 0.24 ab	1.02 ± 0.19 a

± = Standard error; Different letters in the column and by factor indicate significant differences ($p < 0.05$); Hyb*Co = Hybrid dehydrated Cónico corn tostada; Hyb*Chi = Hybrid dehydrated Chiquito corn tostada; Hyb*Pep = Hybrid dehydrated Pepitilla corn tostada; Hyb*Test = Hybrid dehydrated commercial corn tostada; Sol*Co = Solar-dehydrated Cónico corn tostada; Sol*Chi = Solar-dehydrated Chiquito corn tostada; Sol*Pep = Solar-dehydrated Pepitilla corn tostada; Sol*Test = Solar-dehydrated commercial corn tostada. L = Lightness, a* = Red-Green, b* = Yellow-Blue.

3.2. Fingerprint by FTIR: Analysis for Functional Groups Identification

Figure 3 shows the FTIR spectra of all the samples of Tostadas, and Table 5 observes the stretching attributed to different bonds and functional groups belonging to several molecules present in the structure of the samples at different wavenumber regions. At the region of 3000–3700 cm^{-1}, the observed stretching corresponds to hydroxyl (O–H) groups from residual water, polysaccharides, and amino (N–H) groups from partially preserved or thermal-modified proteins [49]. All samples showed medium intensity, suggesting a similar content of hydroxylated structures.

Table 5. Bonds and functional groups identified in tostada samples.

Bond/Stretching	Wavenumber Range (cm^{-1})	Associated Principal Component	Reference
O–H, N–H	3000–3700	Water, polysaccharides, proteins	[49]
C–H	2800–3000	Lipids, polysaccharides (carbohydrates)	[50,51]
C=O, N–H	1500–1750	Amide (proteins), lipids	[52,53]
C–O, C–N,	1200–1500	Carbohydrates, proteins	[54,55]
C–O–C, C–O, C–C, C–H	900–1200	Polysaccharides (carbohydrates)	[56–59]
O–P–O	<900	Phosphates	[60]

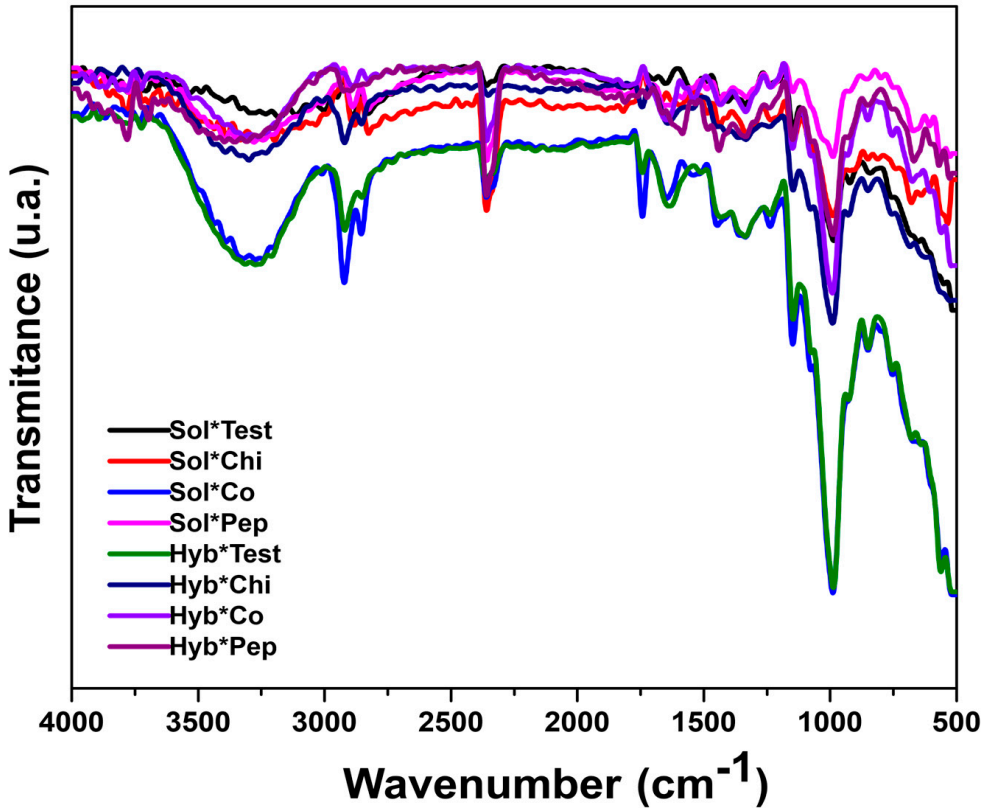


Figure 3. FTIR of tostadas samples. Hyb*Co = Hybrid dehydrated Cónico corn tostada; Hyb*Chi = Hybrid dehydrated Chiquito corn tostada; Hyb*Pep = Hybrid dehydrated pepitilla corn tostada; Hyb*Test = Hybrid dehydrated commercial corn tostada; Sol*Co = Solar-dehydrated Cónico corn tostada; Sol*Chi = Solar-dehydrated Chiquito corn tostada; Sol*Pep = Solar-dehydrated Pepitilla corn tostada; Sol*Test = Solar-dehydrated commercial corn tostada.

The region between 2800–3000 cm^{-1} included symmetric and asymmetric C–H stretching vibrations of aliphatic chains, attributed to lipids and cellular components [50,51]. The minor differences observed among the samples indicated similar lipid composition across maize varieties and lime concentrations.

In the range of 1500–1750 cm^{-1}, carbonyl (C=O) stretching vibrations from proteins and lipids were observed, as well as the N–H bending of (amide I band and II bands), indicative of protein content [52,53]. Hybrid maize samples presented a higher intensity in this region, suggesting higher protein retention or exposure due to thermal processing.

The region from 1200 to 1500 cm^{-1} contained signals associated with C–O (carbohydrates) and C–N (proteins) stretching vibrations [54,55]. The hybrid samples showed higher intensities, particularly associated with higher lime concentrations, indicating enhanced exposure of glycosidic or protein structures.

The range of 900–1200 cm^{-1} was associated with the polysaccharide fingerprint, including characteristic complex vibrations from starch, cellulose, and hemicellulose, which are structural components of plant cell walls and were associated with the C–O–C, C–O, C–C and C–H stretching [56–59]. Also, the structural features present in starch, when partially altered, facilitate the release of free sugars and could improve the perception of sweetness in nixtamalized maize products. This is supported by evidence showing that partial gelatinization during thermal–alkali processes (e.g., nixtamalization) improves the accessibility of starch to enzymatic breakdown, increasing sugar release and sweetness in cereals [61]. Nixtamalized maize starch exhibits increased granule swelling and altered rheological properties, accelerating retrogradation kinetics and potentially improving

sugar availability [62]. In addition, studies on cereal starches have shown that partial gelatinization can modulate starch–sugar homeostasis, influencing enzymatic digestibility and sweetness perception [63,64].

In the hybrid samples, more intense bands were observed, possibly indicating lower levels of gelatinization or more preserved structural features after thermal treatment. The <900 cm^{-1} area is associated with phosphate groups (PO_4^{3-}) and skeletal vibrations of carbohydrate rings [60]. The detection of phosphate-related bands in the infrared spectra was a consistent and significant observation across all toasted maize samples analyzed. This presence can be attributed to a combination of biological origin, chemical transformation during nixtamalization, and the thermal stability of phosphate species during the toasting process [65]. The traditional nixtamalization process involves the use of calcium hydroxide (lime), which raises the pH of the cooking medium and facilitates the partial hydrolysis of phytic acid. This process releases inorganic phosphate ions (PO_4^{3-}), which can subsequently interact with calcium to form insoluble calcium phosphate salts [66]. The residual minerals incorporated during the nixtamalization process, especially calcium and phosphate, may persist in nixtamalized maize products and impart chalky or subtly salty flavour notes, contributing to mineral-related sensory differences [67,68]. In addition to spectral differences, the higher intensity of FTIR bands associated with glycosidic structures (C–O, C–O–C) and proteins (amides I and II) in the hybrid samples could indicate partial gelatinization and exposure of macromolecules. This was in accordance with the higher moisture and fracturability observed in physicochemical tests. This finding is consistent with the conclusions of previous studies, which demonstrated that limited gelatinization can preserve textural smoothness and enhance sensory perception, including sweetness and dough-like mouthfeel [69,70].

3.3. Identification of Significant Sensory Attributes, Emotions and Memories

Table 6 shows the probability values from the ANOVA test for the evaluated sensory attributes. Significant differences were observed in all the sensory attributes evaluated according to the sample and consumer factors. Figure 4 shows the confidence ellipses and the sensory profile of the tostadas. It can be observed that the Hyb*Test and Sol*Test tostadas were perceived as similar, with high lime flavor intensities and hardness. On the other hand, the Hyb*Co, Sol*Co, Sol*Chi, and Sol*Pep tostadas were characterized by a doughy, burnt, corny, salty, and crunchy flavor. However, the tostadas made with Hyb*Chi and Hyb*Pep corn were the only samples that were perceived as different ($p < 0.05$) because they presented higher intensities of sweetness, porosity, and sourness.

Table 6. Probability values for each sensory attribute.

Attribute	Sample		Consumer	
	F	*p*-Value	F	*p*-Value
Crunchy	23.69	<0.0001	3.08	<0.0001
Corn-F	7.86	<0.0001	3.16	<0.0001
Sweet-BT	6.70	<0.0001	6.47	<0.0001
Salty-BT	4.81	<0.0001	6.56	<0.0001
Lime-F	4.89	<0.0001	5.28	<0.0001
Burnt-F	5.77	<0.0001	3.21	<0.0001
Hard	23.95	<0.0001	2.27	<0.0001
Porous	8.40	<0.0001	5.01	<0.0001
Dough-F	4.12	<0.0001	5.16	<0.0001
Sour-BT	3.40	0.001	3.13	<0.0001

F = Flavor; BT = Basic taste.

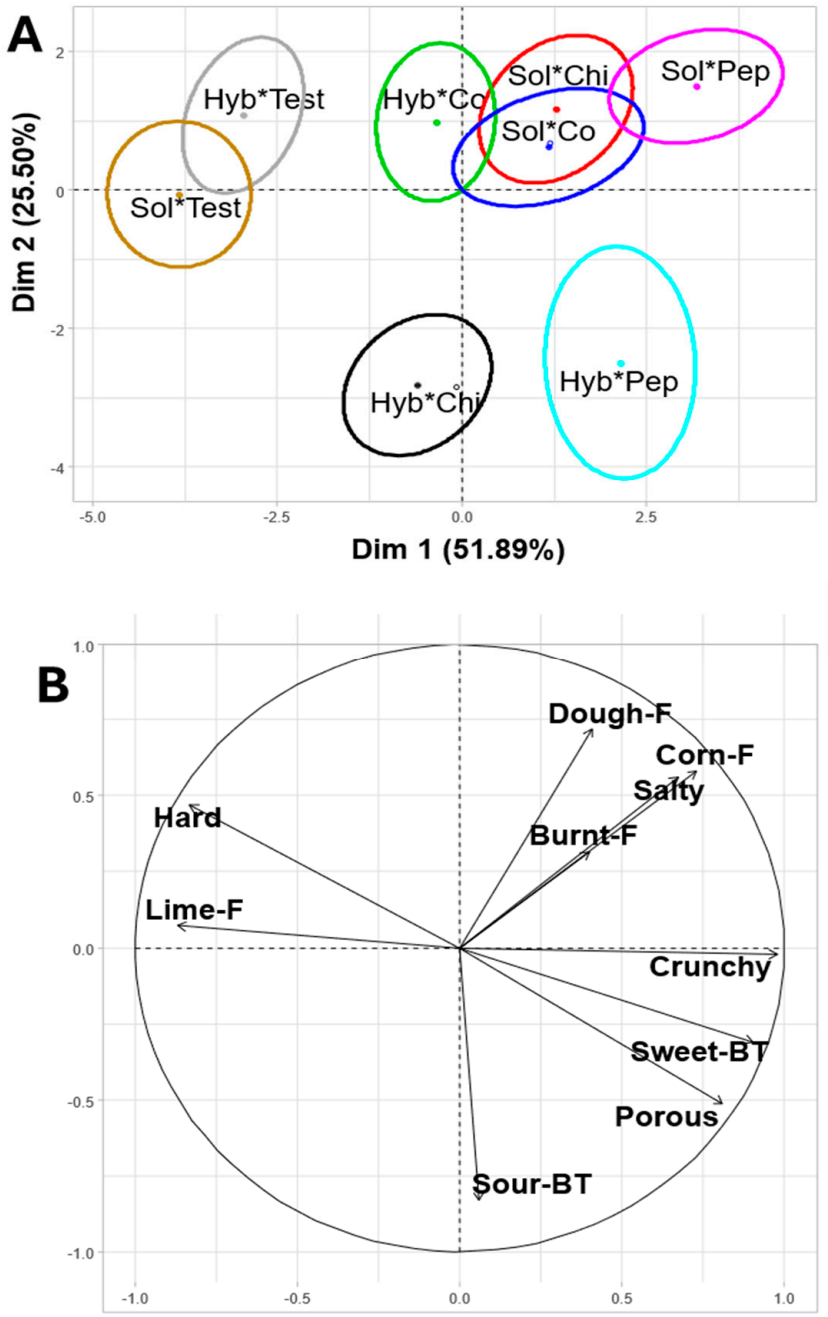


Figure 4. (**A**) 95% confidence ellipses with 500 resamples and (**B**) Sensory profile of tostadas made with corn of different races and dehydration methods. Hyb*Co = Hybrid dehydrated Cónico corn tostada; Hyb*Chi = Hybrid dehydrated Chiquito corn tostada; Hyb*Pep = Hybrid dehydrated Pepitilla corn tostada; Hyb*Test = Hybrid dehydrated commercial corn tostada; Sol*Co = Solar-dehydrated Cónico corn tostada; Sol*Chi = Solar-dehydrated Chiquito corn tostada; Sol*Pep = Solar-dehydrated Pepitilla corn tostada; Sol*Test = Solar-dehydrated commercial corn tostada. (*J* * *I*) *K*, where *J* = 8 tostadas, *I* = 100 consumers and *K* = 10 sensory attributes. Transposed ellipses mean that the samples were perceived as similar and separated ellipses mean that the samples are perceived as different.

3.4. Identification of Significant Emotions and Memories

Table 7 shows the probability values for emotions and memories. It was found that the images of tostadas evoked a total of 18 emotions and 15 memories in consumers. Both positive emotions and memories were mostly evoked (11 positive emotions and 12 positive memories) compared to negative aspects (7 negative emotions and 3 negative memories). The emotions and memories found in this research were also reported by

Cabal-Prieto et al. [9]) and Santiago-Cruz et al. [71] in corn products such as artisanal and commercial tortillas, which evoked the emotions free, good, happy, satisfied, disgusted, bored, mild, nostalgic as well as the memories artisanal food, party, family, alive, hot weather, and mild weather.

Table 7. Probability values of the Cochran's Q test for emotions and memories.

Emotion	*p*-Value	Emotion	*p*-Value	Memorie	*p*-Value	Memorie	*p*-Value
Active (+)	0.414	Warm (+)	0.001	Traditional food (+)	<0.0001	Cold weather (+)	0.973
Enthusiastic (+)	0.275	Satisfied (+)	<0.0001	Party (+)	<0.0001	Hot weather (+)	0.022
Free (+)	0.0001	Calm (+)	<0.0001	Family (+)	<0.0001	Mild weather (+)	0.001
Good (+)	<0.0001	Adventurous (+)	<0.0001	Birthplace (+)	0.105	Disease (−)	0.323
Good nature (+)	0.304	Interested (+)	0.0001	Childhood (+)	<0.0001	Pain (−)	0.001
Happy (+)	<0.0001	Aggressive (−)	0.005	Friendship (+)	0.013	Hurt (−)	0.012
Joyful (+)	0.003	Disgusted (−)	<0.0001	Sport (+)	0.006	Obesity (−)	0.973
Loving (+)	0.716	Nostalgic (−)	0.005	Alive (+)	0.008	Stench (−)	0.398
Mild (+)	0.009	Wild (−)	0.022	Gift (+)	0.009	Addiction (−)	0.550
Pleasant (+)	0.854	Worried (−)	0.045	Spring (+)	0.448	Poverty (−)	0.179
Secure (+)	0.661	Bored (−)	<0.0001	Summer (+)	0.007	Death (−)	0.208
Tame (+)	0.030	Guilty (−)	0.003	Fall (+)	0.548	Interpersonal conflict (−)	0.564
Understanding (+)	0.701			Winter (+)	0.158	Accident (−)	0.015
				Rainy weather (+)	<0.0001		

(−) indicates a negative emotion or memory; (+) indicates a positive emotion or memory. (*J*I*) *K*-dimensional matrix, where J = 8 tostadas images, I = 505 consumers, and K = 50 cognitive words (n = 25 emotions and n = 25 memories).

3.5. Liking Level Based on Physicochemical and Sensory-Cognitive Aspects

The results of the two-way ANOVA (sample and consumer) determined significant differences in consumer preference. The Sol*Pep tostada sample obtained the highest preference value ($p < 0.05$) of 6.5, placing this sample in the "slightly like" region of the hedonic scale (Figure 5). The Sol*Co, Hyb*Pep, Sol*Chi, Hyb*Chi, and Hyb*Co tostada samples obtained preference scores of 5.6, 5.3, 5.2, 5.1, and 5.0, respectively, placing them in the "moderately like" to "neither like nor dislike" region of the hedonic scale (Figure 5), and the control samples obtained the lowest preference value ($p < 0.05$) of 4.2 and 3.1 for the Hyb*Test and Sol*Test tostada, respectively (Figure 5). A total of four consumer classes were obtained using the AHC technique. Classes 1, 2, 3, and 4 consisted of 53, 23, 9, and 15 consumers, respectively.

The response to the preference or rejection of the tostada samples is observed in the PREFMAP vector model (Figure 6). Consumer classes 1, 2, and 4 (91 consumers) preferred (preference contours from 40 to 80% in green and orange colors) the Sol*Chi (Chiquito solar), Hyb*Pep (Pepitilla hybrid), Hyb*Co (Cónico hybrid), and Hyb*Chi (Chiquito hybrid) tostadas because they had a higher protein content, moisture, and high fracturability. Additionally, these samples were perceived as crunchy, porous, and sweet with a doughy, corny, and burnt flavor. The burnt flavor attribute perceived in the tostadas may initially be considered to have a negative connotation; however, for corn tostadas, this term refers to a specific toasted note that is positively valued by consumers. This attribute is associated with toasting and not with an unpleasant characteristic related to a food that has been completely burnt. According to De Santis [72] and Saleh and Lee [73], toasted or burnt notes depend on the context and type of product being analyzed.

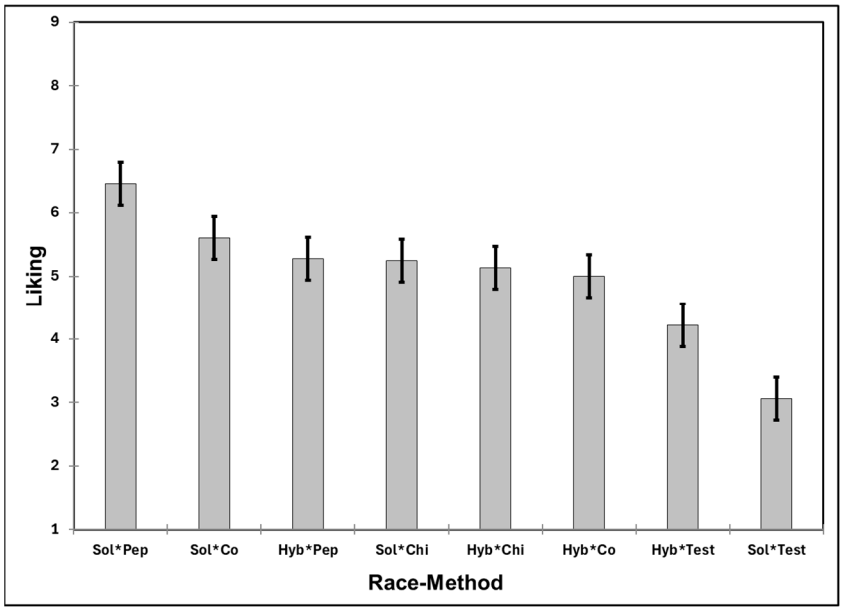


Figure 5. Average liking values of tostada consumers. Hyb*Co = Hybrid dehydrated Cónico corn tostada; Hyb*Chi = Hybrid dehydrated Chiquito corn tostada; Hyb*Pep = Hybrid dehydrated Pepitilla corn tostada; Hyb*Test = Hybrid dehydrated commercial corn tostada; Sol*Co = Solar-dehydrated Cónico corn tostada; Sol*Chi = Solar-dehydrated Chiquito corn tostada; Sol*Pep = Solar-dehydrated Pepitilla corn tostada; Sol*Test = Solar-dehydrated commercial corn tostada.

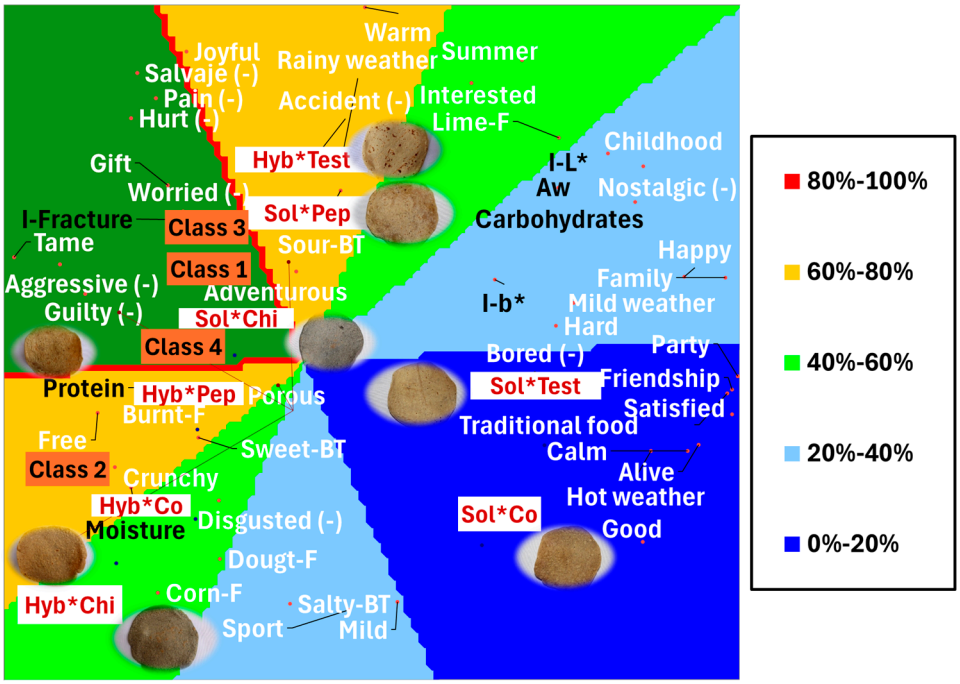


Figure 6. PREFMAP vector model (Yi = α + $\beta_{1\times1}$ + $b_{2\times2}$ + ε) with attributes, emotions, and memories ($p < 0.05$). Class 1 = 53 consumers; Class 2 = 23 consumers; Class = 9 consumers; Class 4 = 15 consumers. a_w = Water activity; I-b* = yellow-blue. (−) indicates negative emotion or memory. I-L = Instrumental luminosity; I-Fracture = Instrumental fracture. Hyb*Co = Hybrid dehydrated Cónico corn tostada; Hyb*Chi = Hybrid dehydrated Chiquito corn tostada; Hyb*Pep = Hybrid dehydrated Pepitilla corn tostada; Hyb*Test = Hybrid dehydrated commercial corn tostada; Sol*Co = Solar-dehydrated Cónico corn tostada; Sol*Chi = Solar-dehydrated Chiquito corn tostada; Sol*Pep = Solar-dehydrated Pepitilla corn tostada; Sol*Test = Solar-dehydrated commercial corn tostada.

From a cognitive perspective, the tostada images evoked both positive emotions (tame, adventurous, free) and negative ones (disgusted, worried, aggressive, and guilty). However, the Hyb*Test (hybrid control) and Sol*Pep (solar Pepitilla) tostada samples were preferred (preference contour from 40 to 80% green and orange colors) by class 3 (9 consumers) because they were perceived as sour and lime-flavored, although the tostadas images evoked more negative emotions and memories (worried, accident, hurt, pain, wild) compared to positive emotions and memories (joyful, warm, rainy weather, summer, and interest). The Sol*Co and Sol*Test tostadas were in the lowest preference contours (0–20% blue), possibly because they evoked negative emotions (nostalgic and bored) and because they had physical characteristics such as high hardness and a yellow to blue color tone.

The results obtained are similar to those reported by Cabal-Prieto et al. [9], who identified the emotions and memories of consumers of artisanal tortillas made with different races of native corn (Cónico, Olotón, Comiteco, Tepecintle and Zapalote) from Mexico and found that these tortillas evoked positive emotions and memories in consumers (adventurous, interested, nostalgic, loving, secure, happy, good, calm, good nature, mild, warm, satisfied, childhood, familia, traditional food, party, friendship, cold weather, hot weather, fall and, sport) and negative ones (disgusted, aggressive, worried, wild, poverty, death, obesity, stench, interpersonal conflict, hurt, pain and, disease). In general terms, several points can be explained: (1) Tostadas made with Pepitilla, Chiquito, and Cónico corn and dehydrated by any of the methods were more preferred, which shows that dehydration by the hybrid method obtained comparable results at a sensorial and cognitive level; (2) The direction of consumer preference for tostadas in this research based on cognitive aspects is in agreement with what was mentioned by Jiang et al. [74], who indicated that positive or negative cognitive aspects play an important role in the acceptance or rejection of food by the consumer; (3) Using the hybrid dehydration method, it was observed that tostada samples from the Pepitilla, Cónico, and Chiquito varieties retained more moisture, and, therefore, a greater diversity of sensory attributes was perceived. The aforementioned is consistent with Calín-Sánchez et al. [75] and Elias et al. [76], who indicated that improvements in dehydration processes can contribute to significantly improving the sensory properties of foods. The results obtained demonstrate the effect of corn race and dehydration type, as well as the interaction between the two, on physicochemical and sensorial-cognitive aspects. However, the limitations of this research make it necessary to conduct further studies in terms of classification to revalue and promote the types of artisanal food that lend identity to the territory where it is produced. In this sense, it is essential to carry out studies that demonstrate the behavior of the tostada during actual consumption using dynamic sensometric techniques to analyze tostada performance in real-time consumption. It is also important to consider various consumer demographic factors such as occupation, consumption context, and intergenerational factors, among others, which have been analyzed in remote research [36,37] with the aim of explaining the impact of these factors on preference, attribute intensity, and the evocation of emotions and memories. Finally, it is necessary to evaluate the economic profitability of solar and solar-hybrid dehydrators in comparison to commercial dehydrators for the production of artisan tostadas.

4. Conclusions

The findings obtained indicate that corn race had an impact on the physicochemical aspects of moisture, lipids, carbohydrates, a_w, L, a*, b*, chroma, and hue angle. The dehydration method only had an impact on the contents of moisture, lipids, ash, carbohydrates, a_w, b*, and fracturability. However, the interaction between corn race and dehydration method had a significant influence on the contents of moisture, protein, carbohydrates, a_w,

L, b*, and fracturability. FTIR results revealed that hybrid samples exhibited higher intensities, particularly associated with higher lime concentrations, indicating greater exposure of glycosidic or protein structures. In the sensory aspect, it is concluded that the tostadas of Pepitilla and Chiquito races made by hybrid dehydration showed intensities of sweet, porous, and acid flavors, while those of the Cónico (solar and hybrid), Chiquito (solar) and Pepitilla (solar) presented high intensities in dough flavor, burnt flavor, corn flavor, saltiness and crunchiness. In the cognitive aspect, it is concluded that both the race and the type of dehydration evoked more positive emotions and memories (11 positive emotions and 12 positive memories) compared to negative aspects (7 negative emotions and 3 negative memories). The results of the PREFMAP vector model conclude that consumers preferred the Solar-Chiquito, Hybrid-Pepitilla, Hybrid-Conico, and Hybrid-Chiquito tostadas because they were samples with higher protein content, humidity, and high fracturability, with high intensities in the attributes crunchy, porosity, sweet, dough flavor, corn flavor, and burnt flavor, which evoked positive emotions (tame, adventurous and, free). For its part, the Solar-Pepitilla tostada samples had a lower preference due to the fact that they were perceived as having a sour, limey flavor, although the tostadas images evoked more negative emotions and memories (worried accident, pain, and wild) although they also evoked some positive emotions and memories (joyful, warm, rainy weather, summer, and interested). However, the Solar-Cónico tostadas were the ones that presented the greatest rejection because this sample was characterized by having physical aspects of high hardness and yellow to blue tones and by evoking negative emotions (nostalgic and bored). The results obtained may be of great interest to the industry responsible for the production of corn tostadas and to small producers in order to give added value to the tortilla and generate greater sources of economic income. Therefore, it is recommended to establish quality control, shelf-life, and traceability programs based on the sensory attributes identified in this research, which were mainly linked to positive cognitive aspects such as emotions, memories, and consumer preference. The aforementioned will allow for the analysis of fluctuations in order to optimize the tostada production process by considering the factors of corn race and dehydration method.

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