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Physicochemical characterization of mesquite flours.

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Abstract

Ethnic foods are healthy products interesting for the new societies. Mesquite flour offers another option for making gluten-free recipes as part of a diet for people with celiac disease. The physicochemical properties of mesquite flours (Prosopis laevigata) were characterized. The mesquite pods were dried at 60°C, 15% RH and 2 m/s airflow; then a grinding and sieving process were applied. The nutritional composition and the sorption isotherms were obtained at 30, 35, 40 and 45°C for water activities of 0.07-0.9. The particle-size distribution, morphology and thermal stability of the flours were determined by different methods.

Keywords: *Mesquite Flours; drying; isotherms; chemical properties; morphology.*

1. Introduction

Mesquite (*Prosopis spp*) are extremophile trees, comprising 44 species around the world [1]. In Mexico, mesquite trees are distributed in northern, central and southern states of the country. In ancient times, the indigenous peoples of Mexico used mesquite pods as food, to produce flour, sirups and bread [2]. The pods having a high protein content in addition to the sucrose content offers a wide potential for the development of new ethnic products [3]. For example, flours of *Prosopis pallida* and *Prosopis juliflora* were obtained from the fractions of different grinds, then a bread was elaborated with 25% wheat flour [4]. In the last years, different studies have analysed the properties of flours of *P. alba, P. chilensis and P. flexuosa* for the elaboration of bakery products. Nevertheless, mesquite flours must satisfy the culinary requirements and the storage conditions must be well stablished [5]. In this work we determine the physicochemical properties of Mexican mesquite flours (*Prosopis laevigata*) in order to characterize the flour and to identify the storage conditions.

2. Materials and Methods

2.1. Mesquite flours

Prosopis laevigata pods were harvested between April and August 2016 in the community of Santiago Suchilquitongo, In Oaxaca (Mexico). The pods in stage three of maturity were used. Pods were dried in a tunnel dryer at 60°C, relative humidity of 10% and air velocity of 2.6 m/s. The pods were milled by two methods: a) in an Osterizer blender model 465-15 for 20 seconds, and b) in a mill pulverizer for legumes Model HC-2000Y, during intervals of 5 seconds until 20 seconds. The milled material was sieved through #40 (0.420mm) and #60 (0.250mm) sieves. After the sieving process the powder was stored in a vacuum desiccator for 24 hours.

2.2. Physicochemical characterization

The moisture content of pods was determined by the oven-dry method (105°C, during 24 hours). The total raw protein content was determined by the Kjeldahl method (AOAC 960.52, 1997). For the determination of reducing and direct sugars, the Lane-Eynon volumetric method was followed. Total fat extraction was carried out by the Soxhlet method (AOAC 920.3, 1990). Raw fiber (NMX-F-090-S-1978) was obtained by using the flour residues, which were dried at 130 °C in an electric oven for 2 hours. The ash content was obtained by calcining in crucibles at 550°C for 30 min in a muffle oven model KLS 03/10.

The particle size distribution of mesquite flour obtained from the pulverizer was analyzed using the principle of blue laser light diffraction measurement (ISO13320, 2009) by the Microtrac Blueray M3551-1W-BU00 in a humid medium, with a measuring range of 10 nm up to 2000 microns. An ultrasound was applied for 30 seconds with a power of 30 watts to

800 grams of flour, then it was divided in three samples to facilitate the dispersion of the particles.

The mesquite flours were analyzed by Scanning Electron Microscope (SEM) in a JEOL brand microscope, model JIB-4601F, with a spatial resolution of 1.2 nm. Secondary electron detector E-T (Everhart-Thornley) and a range of magnification were taken from 50x to 2500x.

The sorption isotherms of mesquite flour were determined by the gravimetric static method with water activities ranging from 0.07 to 0.97 and temperatures of 30, 35 ,40 and 45°C. The used salts were the following: N_aCl, M_gCl_2 * 6 H_2O, KOH, KCl, Kl, K_2SO_6, $M_g(NO_3)_2$ * $6H_2O$ [9]. For high water activities, vials were prepared with an antifungal agent, which were introduced into the equilibrium systems. The samples were weighed every 2 days until constant weight was observed. The experimental data was fitted to the GAB (Guggenheim-Anderson-Deboer) model (Equation 1). The parameters of this model were estimated by using the solver tool in excel [6].

$$\text{Xeq} = \frac{Xm \bullet C \bullet K \bullet a_w}{(1-K \bullet a_w) \bullet (1-K \bullet a_w + C \bullet K \bullet a_w)} \qquad (1)$$

The isosteric heat of sorption (Qst) was determined by solving the equation derived from the Clausius Clapeyron formulation [6] (Equation 2):

$$\left[\frac{\partial \ln(\mathrm{a_W})}{\partial(1/T)}\right]_{CHE} = -\frac{Q_{st}-\lambda}{R} = -\frac{q_{st}}{R} \qquad (2)$$

Samples of mesquite flours conditioned at relative humidity of 7%, 32%, 51% and 67% at 45°C were prepared for a DSC analysis (TA Instruments, model Q2000). The samples started at an initial temperature of 0°C, followed by a heating rate of 2°C /min up to a final temperature of 250°C. The thermogram was obtained by using the TA Instruments Universal Analysis DSC software.

3. Results and Discussion

The nutritional compositions of flours presents a high content of sugars, fiber and protein. It was observed that the carbohydrates increased according to the type of milling, which increases the flour hygroscopicity (Table 1).

***Table 1. Nutritional composition of mesquite flours obtained by the two grindings*.**

Components	**Blender**		**Mill pulverizer**	
	Average (g / 100 g)	Standard deviation	Average (g / 100 g)	Standard deviation
Energy content (kcal / 100 g)	170.97	0.07	198.72	0.50
Carbohydrates (g)	24.27	0.09	26.18	0.08
Sugars (g)	7.48	0.03	10.18	0.02
Proteins (g)	12.4	0.08	11.77	0.12
Fats (Lipids) (g)	2.16	0.03	2.90	0.06
Fiber (g)	16.9	0.2	17.25	0.11
Ashes (g)	3.12	0.01	3.45	0.05
Humidity (g H20 / g dry matter)	0.1	0.01	0.10	0.01

The particle size distribution (Fig. 1) showed a smooth and Gaussian distribution. The flour presented a homogeneous distribution with an average particle size of 148 microns, which is adequate to be considered as flour for bakery and confectionery products.

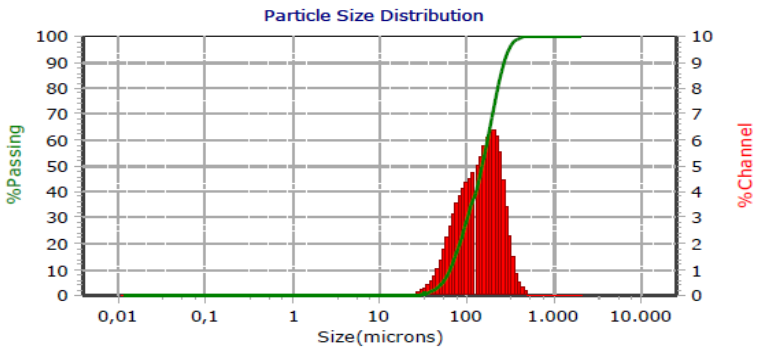

Fig. 1 Particle size distribution.

The SEM images show the morphological characteristics of flours. Figure 2 reveals a surface rounded particle, without rocky parts, or forced cuts. Figure 3 shows a particle organized with smaller particles, forming a tortuous, irregular form, porous, and rocky agglomerate; a strong attraction was observed between the particles with different sizes.

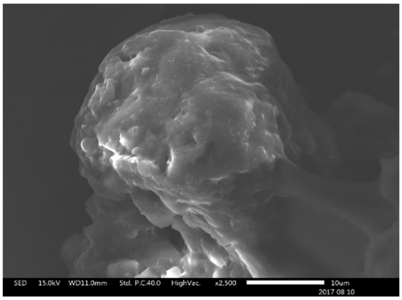

Fig. 2 Micrograph of mesquite flour (Mill pulverizer), 2500x.

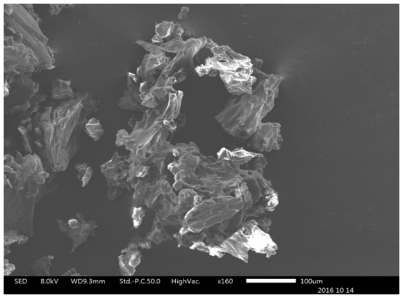

Fig. 3 Micrographs of mesquite flour (Blender), 160x.

The experimental and simulated sorption isotherms at 30, 35, 40 and 45°C are shown in Figure 4, which display a type II form. The shape of the curve indicates a probable small adsorption force in the monolayer [7]. An increase in Xeq was identified when aw is near from 0.65, at this water activity a degradation of flour was observed. This type of isotherm has been obtained in materials containing fibers (wheat, rice, potato, soybean, corn) [8]. Also an interlacing of the curves was observed, indicating a non-dependence on temperature. The GAB model correctly describes the experimental data.

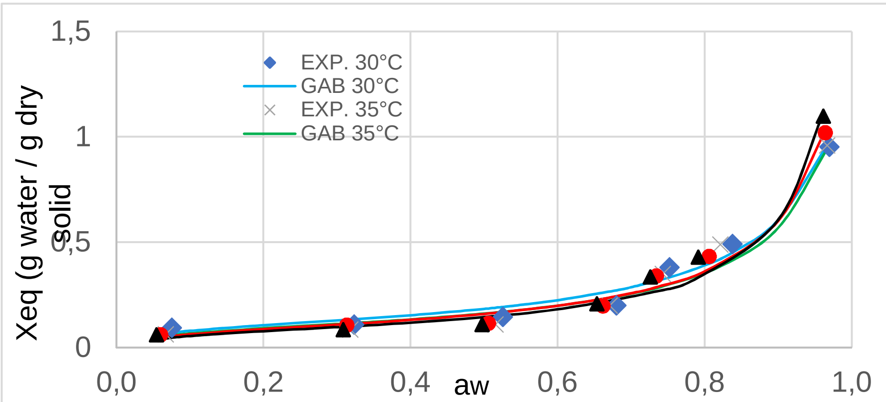

Fig. 4 Adsorption isotherm of mesquite flour (Prosopis laevigata) at the four working temperatures.

Table 2. Parameters obtained from the GAB model

Model	Parameters	30°C	35°C	40°C	45°C
GAB	**Xwa** (g H20 /g dry matter)	0.1039	0.0905	0.0894	0.0824
	C	22.1997	19.9075	16.6142	15.2432
	k	0.9219	0.9355	0.9475	0.9656
	r^2	0.9898	0.9772	0.9817	0.9773
	s	0.0555	0.0741	0.0592	0.0703

Xwa = Monolayer value; C and k = constants for the model; r^2 = correlation coefficient; *s* = standard error

Figure 5 shows the isosteric heat (Qst). Qst increases as Xw decreases; At Xw=0.25 the value of Qst is 47.69 kJ/mol and at Xw=0.05 Qst=81 kJ/mol. This fact indicates a low availability of active sites and liaison forces on the surface of the flour [9]. Qst indicates a requirement of 81 kJ/mol in order to remove 0.05 g water/g dry solid, without affecting the stability of the flour.

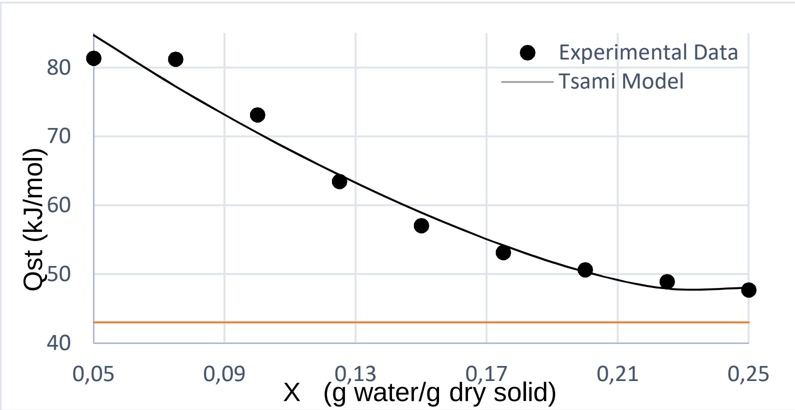

Fig. 5 Isosteric heat of sorption as a function of the moisture content of mesquite flours subjected to constant temperatures of 30, 35, 40 and 45°C.

Figure 6 shows the DSC curves for mesquite flours. A glass transition (Tg) of the mesquite flour was not observed, due to a probable flexibility and mobility of the glucose and fructose chains, as well as the presence and increase in the water content of the sample [10]. The flours displayed a wide thermal stability (0-130°C). The phase transition observed in all the flours were melting points from 148°C to 158°C and crystallizations at 170°C due to the presence of simple sugars, such as fructose.

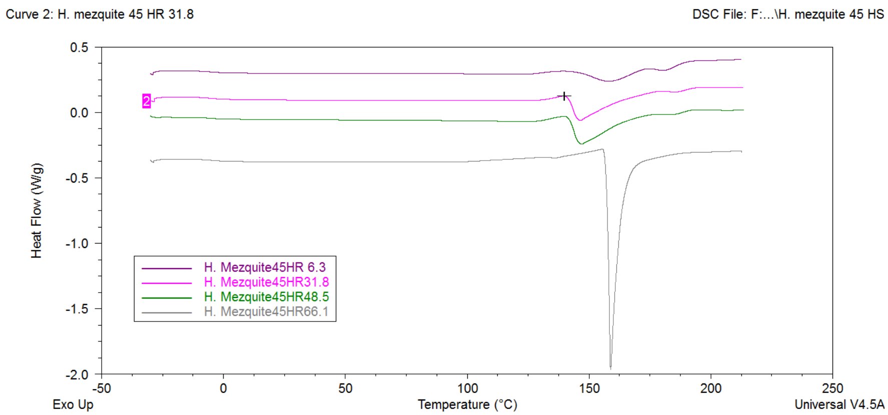

Fig. 6 DSC curves. Flours conditioned at different aw, at 45°C.

4. Conclusions

The nutritional content of the powders reveals important properties for the mesquite flours. Flours have a high content of sugars and fiber, and an important content in protein. Flours are highly hygroscopic, and this fact can be explained by the sugar content. Microscopic images reveal irregular, agglomerated and porous structures. Flour displays a type II isotherm, a water activity higher than 0.6 provoques a degradation of the powders. According to the isosteric heat, 81 kJ/mol are required in order to remove 0.05 g water/g dry solid, without affecting the stability of the flour. The calorimetric data showed a wide thermal stability (0-130ºC) of this material. The flour reveals a potential use for the food industry.

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6. Nomenclature

Subscripts

Xeq	Equilibrium moisture content.
Xm	Monolayer moisture content.
C	Heat-related constant of the monolayer.
K	Heat-related constant of the multilayer.
qst	Net isosteric heat of sorption.

Qst	Total isosteric heat of sorption.
R	Universal constant of the gases.
aw	Activity of water.
T	Temperature.

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