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Attemption to Investigate Drying of Tunisian Cactus Juice for Industrial Use

Houssem Eddine Ben Messaoud[1], Jamel Mejri[2], Khalifa Riahi [3]

[1]Département Génie Mécanique et Agro-Industriel, Ecole Supérieure des Ingénieurs de l'Equipement Rural, ESIER, 9070 Medjez el Bab, Tunisia

[2]Département Hydraulique, Ecole Supérieure des Ingénieurs de l'Equipement Rural, ESIER, 9070 Medjez el Bab, Tunisia

*Corresponding Author: Houssem Eddine Ben Messaoud Tel: +1-514-576-9455
E-mail Address: houssem.ben.messaoud@gmail.com; (H.E.Ben Messaoud)

Abstract: ***This paper aims to contribute to the optimization of a method based on drying and preserving Cactus cladodes juice powder for industrial use. This work expose the analysis of drying cladodes juice, the influence of different additives (Sugar and Salt), drying temperature, water activity and content, drying ratio and velocity, its variation and effect on the characteristic of obtained powder as o bio-flocculent.***

Keywords: cactus cladode powder,drying kinetics, water content and activity, bio-flocculent

1. Introduction

Cactus plant (*Opuntiaficusindica* and *inermis*) is associated with the semi-arid zones of the world and it grows well in areas like Africa, Australia, Mexico and Mediterranean region. The major components of the cladodes are water(91%), carbohydrate (64 - 71%),protein (8.3 - 13.25%) and lipid (2.4 - 7.2%)(Rodrigyez-Felix and Cantwell, 1988; Malainine et *al.*,2003).

Medical research has found value in cladodes as a raw material for products to treat diabetes,high blood cholesterol levels, inflammation, and obesity. Different parts of the plant are also used in the cosmetics industry.

'Nopalitos' have been a traditional fresh green vegetable in the Mexican diet for centuries (Rodriguez-Felix & Villegas-Ochoa, 1988), and for many years have been used and prepared by Mexicans in various ways. In fact, the tender cactus pear pads are an ingredient in a diversity of dishes including sauces, salads, soups, stews, snacks, beverages and desserts (Rodriguez-Felix & Villegas-Ochoa, 1988). Cantwell(1995) mentioned that 'nopalitos' are also a traditional vegetable in some areas of the United States. Good quality cactus stems or 'nopalitos' are thin, fresh-looking, turgid, and a brilliant green. After trimming and chopping, the cactus stems may be eaten as a fresh or cooked vegetable, and resemble green beans in flavor (Rodriguez-Felix & Cantwell, 1988).

A study developed by Rodriguez-Felix et al. (1988)showed that consumers eat 'nopalitos' because they like them and consider it healthy.

Yet other possibilities for cactus cladode processing have been investigated in recent years. There have been many studies on the drying behavior of various vegetable and fruits, also on the prickly pear juice of cactus, and some on cladodes. The approach we took for this study is based on following the water activity and content before and after drying, using a stove and adding Sugar or salt.

The extracted juice from cladodes has shown important results in water treatment.As a bio flocculent, the juice has shown a rapid reaction when added in water. The flocculation process was accelerated, only by using whitewash with or other additives to activate the electronic charges. Many experience were held in this field, the cladodes juice, while added in water, can eliminate; Copper, Zinc and Chrome (Abid& al. 2009a, b).

2. Materiel and methods

2.1. Samples provenance and juice extraction

The prickly pear cladodes used in all the experiments were grown in two regions, Tunis and Bizerte (North of Tunisia). We have used two species of *Opuntia: O.ficusindica* and *O.ficusinermis*. The cladode juice was extracted a day or two after its cultivation, the juice was stored in a refrigerator at 5°C, and were equilibrated for some hours at ambient conditions before drying trial. We used a new juice every 3 days.

2.2. Methods

The experiments are based on thermal drying in a stove adding sugar and salt. The stove was heated at 100°C one hour before starting the experiments. A 200ml juice was mixed with nine different quantity of salt, from 0 to 0.08mg/ml of NaCl. The same with sugar. The juice was dried in petri dish until its mass became constant. The juice was weighted every 10 min. Most of the samples were totally dried after 120 min. Each experiment was repeated 3 times. The average of results was used for the modeling and curve plotting.

2.3. Study of kinetics drying

The juice drying experiments were conducted at 100°C, 9 concentrations of NaCl and Sugar. Using Van Meel's concept (1958) of characteristic drying curve, it is possible to present the drying rate curves of a given product by a single normalized drying rate curve. This curve can be used to generalize data for drying kinetics of prickly pear cladode in a stove. Several authors (Belghit et al. 2000;Bellegha et al. 2002; Kouhila et al. 2002), based on the Van Meel transformation, have used simply the initial moisture content (M_0) and the equilibrium moisture content (M_e) to obtain moisture ratio Xas follows ;

$$\boldsymbol{X} = \frac{\boldsymbol{M-Me}}{\boldsymbol{Mo-Me}} \quad (1)$$

$$\boldsymbol{f} = \frac{\left(-\frac{dM}{dt}\right)}{\left(-\frac{dM}{dt}\right)_{o}} \quad (2)$$

Where, MR is the moisture ratio and f the dimensionless drying rate. The equilibrium moisture content M_e is determined by;

$$\boldsymbol{Me} = \frac{\boldsymbol{M-Ms}}{\boldsymbol{Ms}} \quad (3)$$

Where Mis the moisture at't' time and $M_s$is the dried matter.

The drying rate is given by$\boldsymbol{X'} = \frac{\boldsymbol{dX}}{\boldsymbol{dt}}$

2.4. Bio-flocculent activity

The dried powder was used for water treatment to eliminate phosphor. 100 ml of wastewater was mixed with 0.3 g of calcium oxide. Then left for decantation for about 10min. when we see a 2 separated phases, 30 ml of the water was used for a flocculation. 0.6 g of dried juice powder was used. The mix was mixed at medium speed (500 tr/min) for about 2 min then left for flocculation for 30 min. Finally, a spectrophotometer was used to measure the absorbance and the yield was calculated. All is conducted from the Jar Test method.

Juice Yield values are based on the absorbance which is

given by $R = \frac{N0-Nf}{N0} \times 100$

With:N_0 : initial absorbance

N_f : Absorbance alter traitement

Initial absorbance was 1.43 for experiences with dried powder and 1.7 for concentrated juice.

2.5. Water activity measurements

The water activities of the samples were measured at 20±1 °C with a water activity meter (Testo 650, Testo Inc., NJ, USA). For this purpose, approximately 2 g of each sample was put into the sample holder which was equipped with a meter having a relative humidity and temperature sensor. After equilibration, Aw values were recorded.

3. Results and Discussions

For both experiments, with sugar or Sodium Chloride mixed with, the drying curves of the cladode juice were obtained with reproducibility at different drying conditions. These curves are a plot of moisture content and moisture ratio MR against drying time (Exemple Fig 1). It is clearly evident that they decreased dramatically as drying time increased from 0 to 150 min at a constant Temperature of 105°C.

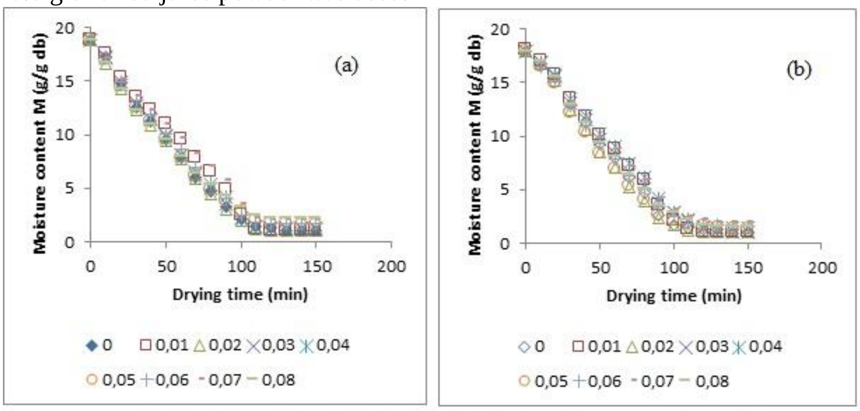

Fig. 1 Variation of moisture content as a function of time for different concentration of NaCl-
O.f. indica (a) - O.f. inermis (b)

The drying rate curves fig 3 and 4 show that the process can be observed by one rate of drying: the falling drying rate period. Drying during the falling rate period is governed by water diffusion in the solid. These results are in agreement with the observations of earlier researchers (Khouhila (2001);Lahsasni et al 2004a,b). This is a complex mechanism involving water in both liquid and vapor states, wich is very often characterized by a so-called 'effective diffusivity'(Lahsasni et al.2003a,b). It is known that this propriety is a function of temperature, pressure and moisture content (Karel 1988).

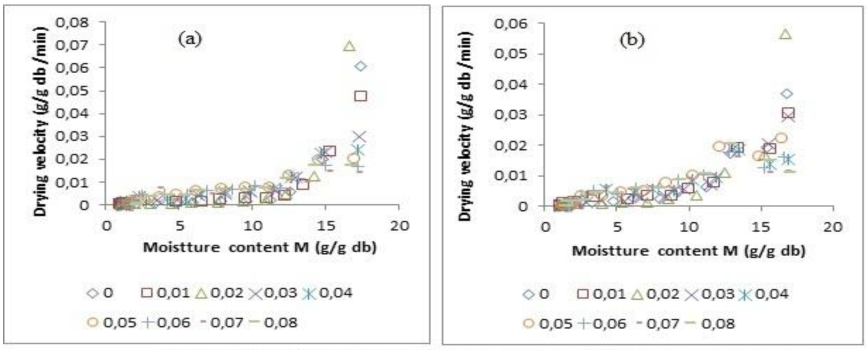

Fig. 3 Variation of drying rate as a function of moisture content for different concentration of NaCl- *O.f. indica (a) - O.f. inermis (b)*

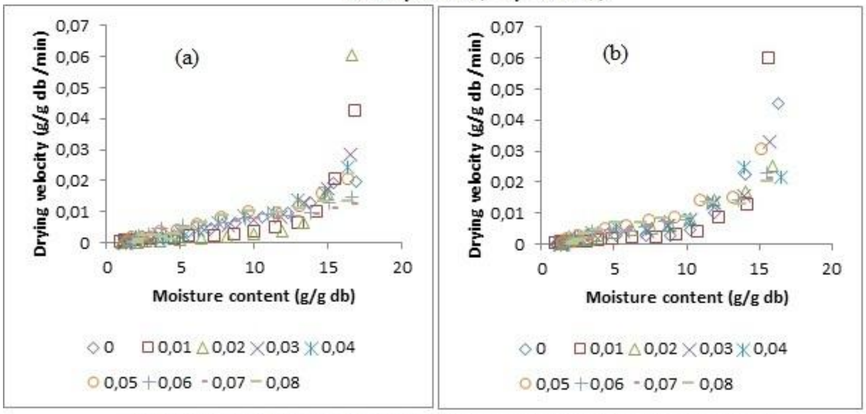

Fig. 4 Variation of drying rate as a function of moisture content for different concentration of sugar- *O.f. indica (a) - O.f. inermis (b)*

The same curve allures were determinated by Belghit et al.2000. Comparing our results to those of Lahsasni et al.(2004a,b), it is obvious that the drying rate increases considerably with increase in drying air temperature.Thus, a higher air temperature produced a higher drying rate consequently the moisture content decreased. These results are in agreement with the observations of earlier researchers (Kechaouet al.1996; Belghit et al. 2000; Kouhila 2001; Kouhila et al. 2002; Lahsani et al. 2004a, b). As the moisture content M decreases, the moisture ratio MR will too similarly. The dried matter will automatically increase, its percentage will increase till it became constant; and that mean the juice has because a powder.

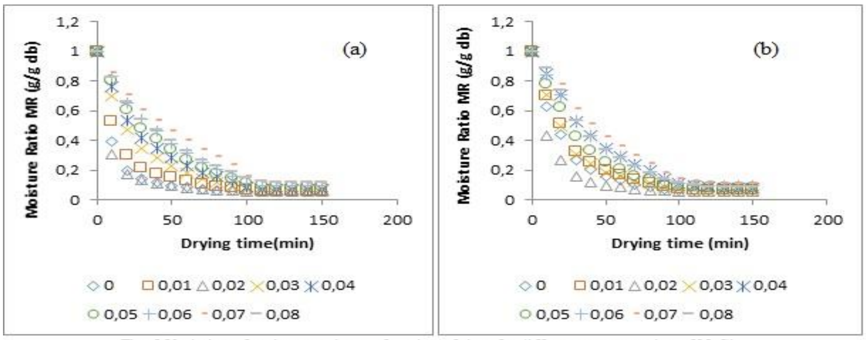

Fig. 5 Variation of moisture ratio as a function of time for different concentration of NaCl- *O.f. indica (a) - O.f. inermis (b)*

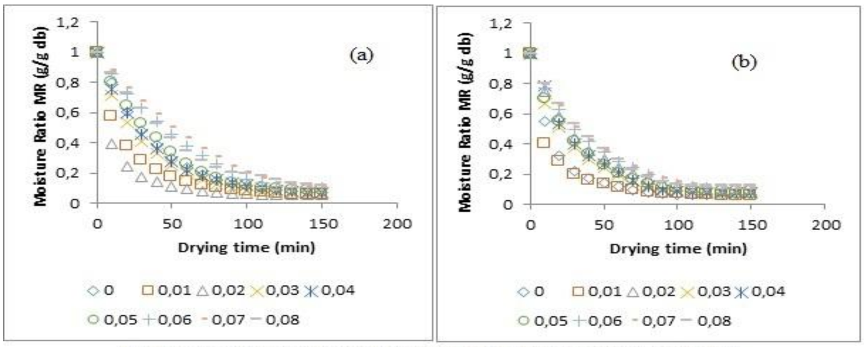

Fig. 6 Variation of moisture ratio as a function of time for different concentration of sugar- *O.f. indica (a) - O.f. inermis (b)*

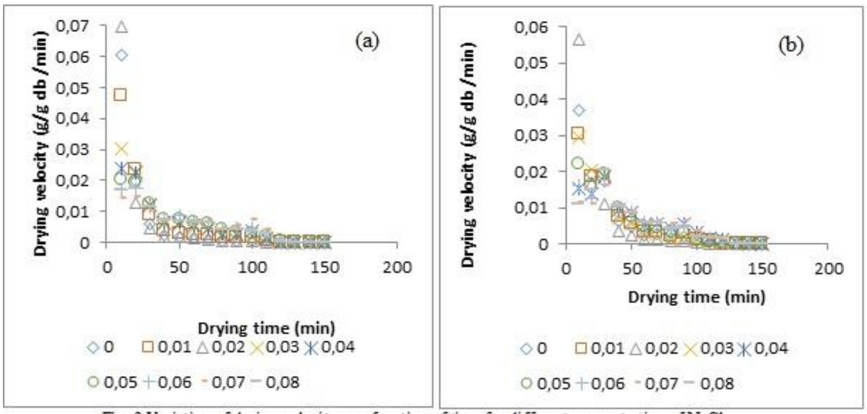

Fig. 9 Variation of drying velocity as a function of time for different concentration of NaCl-
O.f. indica (a) - O.f. inermis (b)

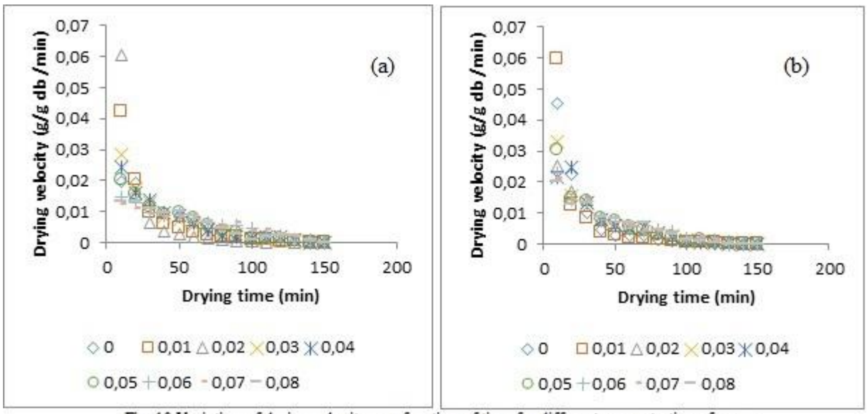

Fig. 10 Variation of drying velocity as a function of time for different concentration of sugar-
O.f. indica (a) - O.f. inermis (b)

The same curves allures were found by Belghit et al. (2000) when interpreting the results of drying kinetics of the verveine. The drying velocity concluded from the Moisture Ratio variations is similar. That shows us a similar reaction of water content elimination and the drying rate phases. In fig 11 and 12 experimental drying data are plotted to represent f=f(MR). These figures show that all drying curves obtained with the moisture ratio X, and dimensionless drying rate f,for different tested conditions, are close together(Lahsasni et al., 2003)

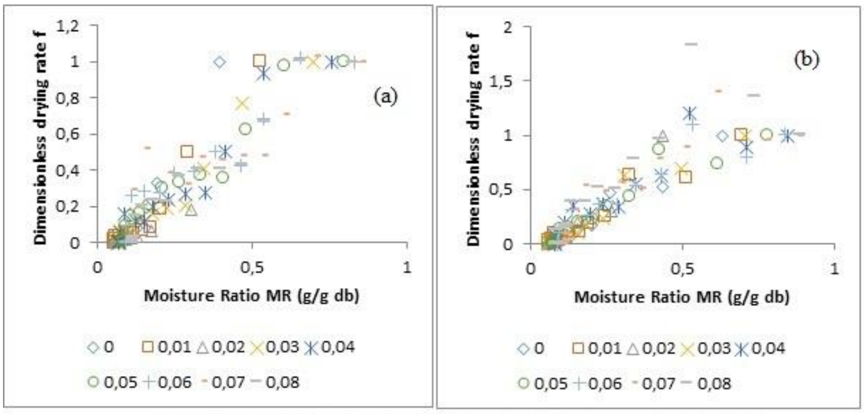

Fig.11. Characteristic drying curve of prickly pear cladode for different concentration of NaCl- *O.f. indica (a) - O.f. inermis (b)*

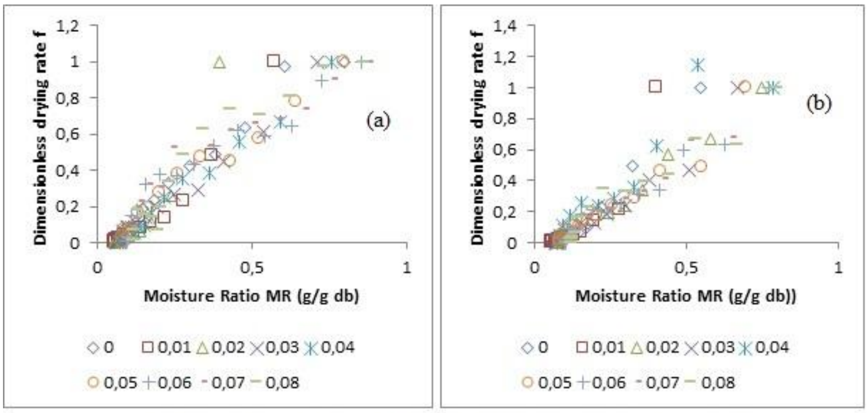

Fig. 12 Characteristic drying curve of prickly pear cladode for different concentration of sugar- *O.f. indica (a)* - *O.f. inermis (b)*

4. Water Activity Measurements

For the indica variety, juice water activity was 0.932 and 0.920 for the inermis one. The moisture content was reduced until we had a constant weight. The drying process aims to reduce the water in the aliment for a longer conservation. A simple drying process may be enough to reduce water or eliminate it, but most important is to reduce the bounded water. The values shown in table are measured about 2 months after the dried process took place.

	O.F .indica	*O.f .inermis*		*O.F. indica*	*O.f. inermis*
Concentration of NaCl (mg/ml)	Aw		Concentration of sugar (mg/ml)	Aw	
0	0.425	0.453	0	0.430	0.444
0.01	0.418	0.449	0.01	0.395	0.421
0.02	0.420	0.443	0.02	0.325	0.395
0.03	0.428	0.446	0.03	0.358	0.391
0.04	0.438	0.452	0.04	0.355	0.389
0.05	0.449	0.448	0.05	0.365	0.39
0.06	0.452	0.438	0.06	0.359	0.424
0.07	0.435	0.454	0.07	0.408	0.419
0.08	0.421	0.467	0.08	0.409	0.427

The relationship between water activity and water content in a product is often expressed as a sorption isotherm. The typical form of an isothermal reflects the manner in which water is connected to the system. Until water activity of about 0.30, the water is considered held for polar sites of relatively high energy. This is called the monolayer. The water activity in the range of 0.30 to 0.70 is called multilayered water. It consists of layers of water, which are adsorbed on the first layer by hydrogen bonds.

Many models predicting the relationship between the equilibrium moisture content, water activity and temperature have been developed (Van den Berg et al. 1981). Henderson and BET are models that describe very well the moisture sorption of various foods (Kouhila , Belghit and Daguenet , 2001).

The value of the water activity of various food prescribed in the United States since 1979 by the FDA (Food and Drug Administration). According to the recommendations of the FDA, a food product is considered stable with a limited microbiological growth must not have a water activity higher than 0.5.

Initially, the water activity of fresh juice is 0.932 for O.f. indica and 0.920 for the inermis one. The value of the activity varies depending on the variety of cactus, also the concentration of sodium chloride or sugar . These values for the indicavariety, vary between 0.418 and 0.452 for concentrations of 0.01 and 0.06 mg / ml NaCl respectively. These are 0.325 and 0.430 for concentrations of 0 and 0.02 mg / ml of sugar respectively. For inermis variety, the water activity is 0.438 in a concentration of 0.06 mg / ml of NaCl and 0.467 in 0.08 mg / ml NaCl. For a concentration of 0.04 mg / ml of sugar, the water activity is 0.389 and 0.428 for drying without addition of sugar.

5. Effect of concentrated juice on synthetic water treatment

Several tests were conducted in order to find the proper amount of powder for the treatment of a volume of waste water.
The results obtained are shown in the following table

Specie	Yield (%)
O.f. indica	84
O. inermis	41.20

The results obtained by the oven-dried powder are satisfactory when it comes to yield. But the quality of powder is not good. During the various tests, a color change was remarkable in the water to be treated, as the non-complete dissolution of the powder.

6. Conclusion

In this study, cladode cactus juice drying tests were conducted for *O.f.indica* and *O.inermis* at 105°C. From the results obtained, it was observed that only the falling drying rate period exists.The characteristic drying curves were obtained and there expressions were determined. These CDC can be used to generalize date for drying kinetics of cladode juice drying. The page equations were the best models to fit the experimental data. Drying parameters in these models were quantified as a function of the drying air temperature. The yields obtained in water treatments are to be optimized.

7. Nomenclature

db: Dry basis
$(-dX/dt)_0$: Initial drying rate (g/g db/min)
(-dX/dt): Drying rate at any time of drying (g/g db/min)
F: Dimensionless drying rate
M: Moisture content at any time of drying (g/g db)
M_0: Initial Moisture content
M_e: Equilibrium moisture content (g/g db)
M_s: Final Moisture content (g/g db)
T: Drying temperature (°C)
T: Drying time (min)
X: Moisture Ratio (g/g db)
Aw: Water Activity
R : Juice yield in water treatment (%)
N_0 : Initial absorbance
N_f : Absorbance alter traitement

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