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Study of Nutritional Composition of Nopal (*Opuntia ficus indica* cv. Redonda) at Different Maturity Stages

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Abstract: Nopal is included in the human diet and used as forage, which is interesting vegetal due to its environmental resistance, but little is known about its nutritional properties along the maturity stage. The objective of this study was to determine the development of the of nopal (*Opuntia ficus indica*, cv. Redonda*)* composition at advanced maturity stages in order to evaluate the age related changes in the nutritional composition for suggest its potential use for human consumption. Chemical proximate analysis, mineral constituents and amino acid profile were carried out at different maturation stages. Insoluble dietary fiber, calcium increased from 17.95% to 34.40% from 40-135 days respectively. In addition the ash and phosphorus content also increased. The soluble dietary fiber in nopal decreased as age progressed from 40 to 135 age days. Data also showed that nopal contain 17 amino acids and nine of them are considered essential. The results show that older nopal is an important source of calcium and dietary fiber. Nopal can be an economic alternative for use as food supplement mainly at advanced maturation stage i.e. at 135 days and can be ameliorate or prevent the chronic and degenerative disease.

Keywords: Calcium, chemical composition, vegetables, natural products, nutritional aspects.

INTRODUCTION

The nopal (*Opuntia ficus indica)* is widely distributed in Mexico and in all American Continent and grow in many other regions of the world, such as Africa, Australia and the Mediterranean [1] Nopal is included in for the Mexican human diet. The cactus pads are commonly called nopales as fresh young nopal from 3-4 weeks of age. Nopales are traditionally consumed in Mexico and in the Unites States, prepared with several different cooking methods. They are usually consumed as salads, but the older stage varieties are also used as cooked consumption items. The advanced mature nopales are sometimes used as forage when fresh food is insufficient due to scarcity of rain. The nopal is cheap, plentiful and the plants have also been used for erosion control [2].

It´s important to emphasize the potential nutrimental values related to older maturational stages which currently only represent use primarily for animal forage. No consideration has been made regarding its it´s potential use as nopal powder. This is unfortunate as it contains some essential nutriments that help to maintain human health. The benefits associated with fiber content are well known, especially for ameliorated the symptoms of diabetes, through the reduction of glucose values in the blood, anti-hyperlipidemic and hypercholesterolemic effects [3-6]. A previous study showed that young nopal used for human consume, are rich in calcium (Ca) which increases with nopal age, but has not been investigated extensively [7]. In addition, other studies also demonstrated that nopal possesses a higher content of Ca than other vegetables included in the diet [8,9]. Ca is consider an important mineral component for bone metabolism, for that reason, the knowledge of natural sources included in the daily diet, nopal could be an excellent complement of food in order to complement dietary nutritional intake and contribute to for the prevention of some osseous disorders such as osteoporosis. The nopal is an important source of nutritional elements for example pectin, mucilage and minerals. Currently there is only information related to young maturational stage, but little is known about the nutritional value of the older maturational stages. The fresh young cladodes are a source of proteins including essential amino acids, and vita-

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mins. Several studies have reported that high levels of amino acids especially proline, taurine and serine are found in nopal [1,9,10]. In contrast not much information is available about amino acids profile at the older nopal ages. Also is noteworthy that there is a gap substantial gap in the studies regarding the nutritional and mineral content at advanced ages of the nopal.

The objective of this work was to evaluate the chemical composition and mineral content of nopal (*Opuntia ficus-indica*, cv. 'Redonda') at different maturity stage from 40 to 135 days, in order to determine the nutrimental contribution for human and animal diets.

MATERIALS AND METHODOLOGY

Nopal of *Opuntia ficus indica* cv. 'Redonda' established in the experimental station of the Universidad Nacional Autonoma de Mexico, located at "Los Lores" farm, in Silao, Guanajuato Mexico during the summer period of July to August, 2007. Each sample was made up of 4 kg of which was collected from several plants in the same sampling areas at different maturity stages from 40 to 135 age days. Samples were then transported to the laboratory and were classified and separated in ten groups according to their age (40, 60, 80,100,115,125 and 135 days respectively).

Dry Vacuum Process

Nopal was dried using a vacuum system for 12 hours at 10^{-2} Torr, and 45 ºC, in order to avoid protein and carbohydrate damage. They were then washed with distilled water and disinfected using commercial 10% sodium hypochlorite solution in order to eliminate microorganisms, the thorns were manually removed and the nopal pads were cut in small sections in order to facilitate the drying process. Finally, the nopal was pulverized to obtain a powder, using a hammer mill (PULVEX 200, Mexico) equipped with a 0.5 mm screen.

Chemical Proximate Analysis

Moisture of the nopal flours was determined by desiccation at 40 ºC for 24 h, in accordance with the 934.01 method previously described in publication from the Association of Official Analytical Chemists 2000 (AOAC) [11].

Nitrogen (N) content was obtained by the Kjeldahl method [11], using a 0.5 g sample. The amount of protein in most materials is calculated by multiplying % N by 6.25, because most proteins contain 16% N. In the present study the protein composition was estimated using a nitrogen factor of 6.25.

Soluble and insoluble dietary fiber was determined according to the 991.42 and 993.19 AOAC [11] methods. Fat was analyzed by petroleum ether extraction using a Soxhlet apparatus also according to the 920.39 AOAC methods [11].

Ash and Mineral Composition Evaluation Processes

Ash content was evaluated with the 942.05 AOAC methods [11], using 2 g sample, determined at 550 ºC for 24 h. Mineral content of nopal was evaluated by atomic absorption spectroscopy (AAS), using an AAS equipment and mass spectrometry ICP-MS in the nopal powders.

For the analysis of Ca, Mg, K, Na content was using the dry-ashing procedure 968.08 was used [11]. The Ca, Mg, K, Na ions concentration were measured with a double beam atomic absorption spectrometer.

Quantifications of phosphorus (P), manganese (Mn) iron (Fe), zinc (Zn), of nopal powder were carried out by means of mass spectrometry ICP-MS. The tests were performed following the method of AOAC (984.27) (AOAC, 2000) using a Thermo Jarrel Ash, Model IRIS/AP (Corp. Franklin MA USA). Because the equipment scanning all these bulk elements, they were measured but not reported important age related changes.

Extraction and Quantification of Protein

The protein extraction was achieved according to the Landry [12] methodology. The method described by Hurrell [13] was employed to determine the reactive lysine. The average value of four replicates was reported as g of lysine/100 g of protein.

Proteins were hydrolyzed and amino acids were analyzed using a HPLC autoanalyzer (Waters 2487, Millipore, MA), following a previous reported method [14]. The tryptophan analysis was made by using the HPLC methodology [15]. The *in vitro* protein digestibility of dry samples were estimated applying the equation $Y = 234.84 - 22.56X$ where Y is the *in vitro* protein digestibility (%) and X is the pH of the protein sample suspension, after proteolysis with a multienzyme system [16].

Statistical Analysis

Data, based on three replicate samples were subjected to analysis of variance. Standard deviation of each individual nutrient of each of the maturity stages mean was computed and variations between maturation stages were evaluated by using ANOVA test and linear regression, in order to evaluate the age related changes. The post hoc analysis was made using a Tukey test at a ($P \leq 0.05$). All statistical data were calculated using Statgraphics plus 5.1.

RESULTS

Fat content showed a tendency of decrease but no significant differences related to age were observed as a function of age (R^2=.3319). Protein content, no statistically significant differences were observed when compared the values along the studied ages, no direct relationship (R^2=.179) between protein content and nopal age was observed (Table **1**).

The fiber content of nopal increased from 11.00 g to 23.33 g from 40 and 135 age-days respectively. The regression test showed direct relationship between the nopal maturity stage and fiber content (R^2=.8462) (Fig. **1**).

The insoluble dietary fiber content increased from 40.14 g to 56.82 g, from 40 to 135 days but no showed proportional relationship (R^2=0.1381). The soluble dietary fiber decreased from 25.5 g (40 days) to 9.8 g (135 days) and exhibited a direct relationship with the age of the nopal (R^2=0.6523) (Fig. **1**). No statistically significant differences were observed when compared protein content values at all studied ages.

In relation to amino acid content, data demonstrated that nopal contain 17 different amino acids, threonine and iso-

Table 1. Chemical Composition of *Opuntia* Dehydrated Nopal on g/100 g of Sample (*Opuntia ficus indica* Redonda Variety)

Nopal pads age (days)	Moisture (g)	Ash (g)	Fat (g)	Protein (g)
40	5.03 cd	17.65 a	2.16 e	7.07 b
50	8.81 e	19.59 b	2.37 f	8.99 e
60	5.43 d	20.64 c	2.38 f	8.39 d
70	4.85 bcd	21.09 d	1.62 bc	8.92 e
80	4.36 ab	21.64 e	1.53 ab	7.25 b
90	4.81 bc	21.92 f	1.50 ab	7.78 c
100	4.08 a	22.80 g	1.42 a	8.29 d
115	4.58 abc	22.91 h	1.72 c	8.48 d
125	4.35 ab	20.91 i	1.70 c	5.85 a
135	4.18 a	24.30 j	1.87 d	7.07 b

Mean values ±SE followed by the same letter in lines did not showed statistically significant differences ($P \leq 0.05$) Tukey test.

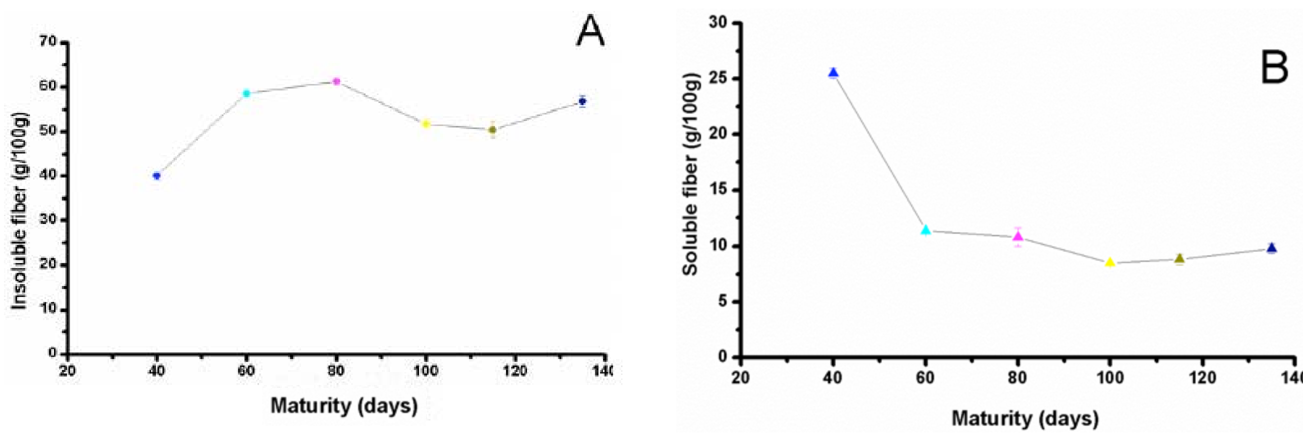

Fig. (1). Concentration of Insoluble fiber (**A**) and soluble fiber (**B**) as a functio n of maturity stages. Values are means +/- SD from triplicates samples.

leucine diminished along the studied ages. Valine, metionine and tryptophane content were increased at 60, 80 and 50 days, respectively. For the histidine, leucine and lysine, the data revealed an increase related to age. The main component of amino acids corresponds to phenylalanine, threonine and isoleucine for all studied maturity stages (Table **2**).

The mineral ash composition increased from 17.65 for 40 days to 24.30 for 135 days. The lineal regression analysis showed a positive relationship (R^2=0.7158) with nopal age. The Ca and K (Fig. **2**) and Fe composition increased from 40 days to 135 days old. Whereas P, Mn, Zn. Mg, and Na showed statistically significant changes, but without a clear trend according to age (Table **3** and Fig. **2**).

DISCUSSION AND CONCLUSIONS

The nopal powders showed a great decrement in the humidity in relation to the fresh nopal inherent to the vacuum drying process; this procedure prevents the proliferation of microorganisms to render the pads edible (Table **1**) [17].

The fat content of powders had minimal differences with tendency to decrease in older ages was observed, perhaps due to physiological changes determined by environmental factors such as availability of water (Table **1**).

The insoluble dietary fiber content showed a positive relationship related to the age, however, the soluble dietary fiber tended to have a negative relationship, suggesting that older nopal is better source of insoluble fiber (Fig **1**). The beneficial health effects of nopal consumption may be due principally to the soluble and insoluble fiber content. In addition, another associated benefit to the fiber composition of the nopal was a decrease observed in the LDL-cholesterol and triglycerides that were observed when the human individual intake supplemented diet with nopal supplemented diet [4,5,18-22].

For protein, no related changes were observed, which was low for all studied ages and similar to those of other vegetables [23] (Table **1**). Findings suggest that physical conditions such as water availability, temperature, and light-dark periods are primarily implicated in protein synthesis. Several studies demonstrated that protein synthesis increasing as a cellular protection when the soil is too acid or saline [24-26].

Table 2. Amino Acids Contained in Nopal *(Opuntia ficus indica)* as a Function of Maturity Stages (g/100g of Protein)

	Age (days)						
Amino acid	**40**	**50**	**60**	**80**	**100**	**125**	**Protein pattern[2]**
Aspartic acid	0.51	0.56	0.66	0.62	0.66	0.62	-
Glutamic acid	1.29	1.53	1.81	1.93	1.87	2.22	-
Serine	0.32	0.47	0.42	0.46	0.56	0.65	-
Glycine	0.27	0.37	0.31	0.36	0.43	0.44	-
Histidine[1]	0.13	0.19	0.11	0.16	0.16	0.17	2.20
Arginine	0.15	0.14	0.14	0.16	0.18	0.16	7.54
Threonine[1]	1.53	1.56	1.31	1.39	1.25	1.21	4.70
Alanine	0.49	0.48	0.42	0.53	0.45	0.41	-
Proline	0.42	0.54	0.64	0.46	0.31	0.34	-
Tyrosine	0.39	0.17	0.19	0.21	0.16	0.14	-
Valine[1]	0.50	0.63	0.73	0.54	0.58	0.51	6.60
Methionine[1]	0.19	0.12	0.15	0.19	0.12	0.13	5.70
Isoleucine[1]	0.70	0.76	0.61	0.64	0.64	0.67	5.40
Leucine[1]	0.85	0.64	0.75	0.61	0.81	0.91	8.60
Phenylalanine[1]	1.69	0.93	1.39	1.36	1.21	1.61	9.30
Lysine[1]	0.52	0.44	0.48	0.56	0.52	0.67	7.00
Tryptophan[1]	0.15	0.19	0.17	0.14	0.15	0.17	4.70

[1]Esential amino acid.
[2]Egg corresponding values [28].

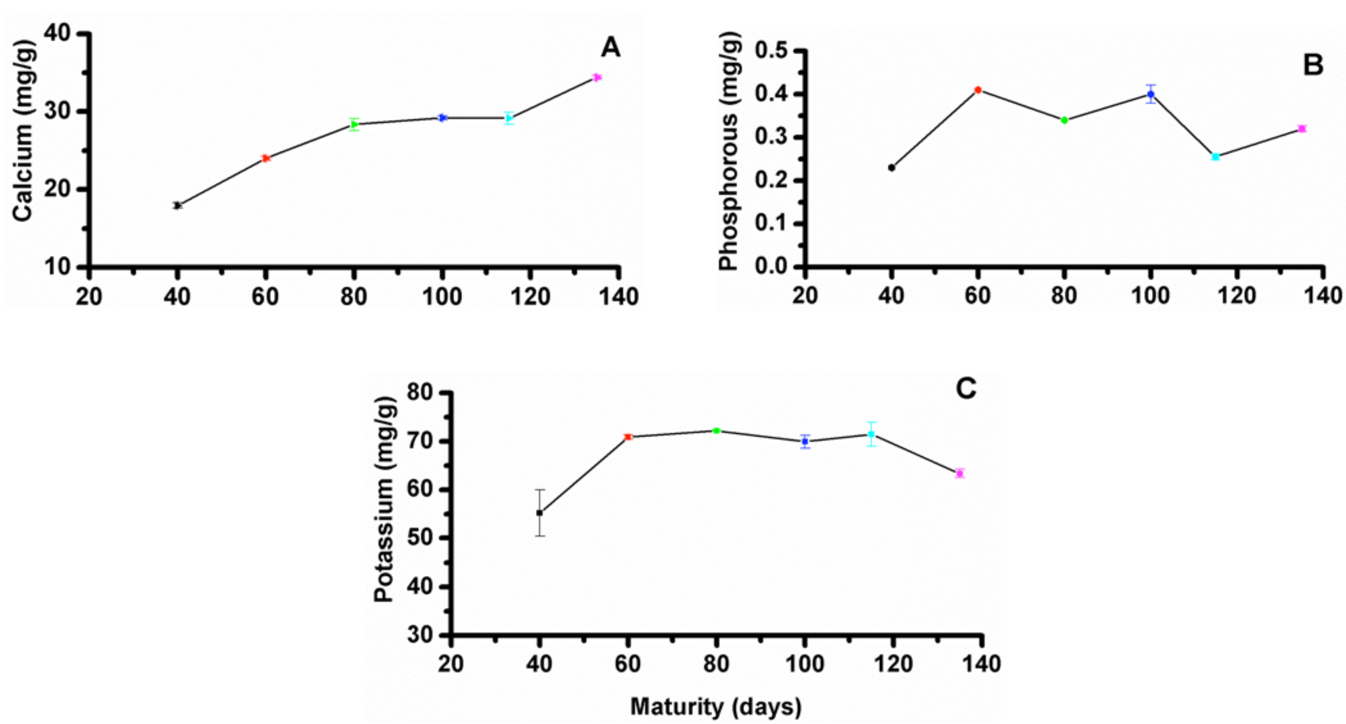

Fig. (2). Calcium concentration (**A**), phosphorous concentration (**B**) and potassium concentration (**C**) of nopal pads at different maturation stages (days). Values are means +/- SD from triplicates samples.

Table 3. Mineral Composition, of Nopal Powder at Different Maturational Stage (Age-Days)

Mineral (mg/g)	Maturity stage (age-days) (mg/g)					
	40	60	80	100	125	135
Manganese	0.29	0.07 a	0.08 a	0.05 a	0.03 a	0.08 a
Iron	0.09 a	0.10 a	0.12 b	0.13 bc	0.16	0.22
Zinc	0.07a	0.08a	0.03b	0.07a	0.04b	0.08a
Magnesium	8.80 a	11.20 f	10.2 d	11.00 f	8.95 b	9.55 c
Sodium	0.30a	0.30a	0.55b	0.20c	0.20c	0.30b

Mean values ± SD followed by the same letter in lines none showed statistically significant differences ($P \leq 0.05$) Tukey test.

In relation to the amino acid content, analyses showed that nopal contain **17** different amino acids, nine of which are considered essential, and showed different levels of content related to the maturity stages. For instance threonine and isoleucine diminished in relation to age, suggesting that younger samples are better source for these amino acids. For the histidine, leucine and lysine content, the data revealed an increase associated with older ages. Finally the major content of amino acids corresponds to phenylalanine, threonine and isoleucine for all age groups. These findings suggest that the nopal powders might be a good complement to other vegetables, meat and dairy products included in daily diets due to their essential amino acids content, see Table **2**.

The ash content of minerals Ca and Fe were increased from 40 to 135 days old samples, whereas P, Mn and Zn not showed age related changes. Further suggesting that some elements of ash chemical composition depend on different factors, such as pH, water availability, soil texture and composition where the nopal grow. Previous studies reported that the main elements in ash are Ca and potassium, followed by magnesium, sodium, and small quantities of iron and manganese (Table **3** and Fig. **2**). These elements are present in carbonates, chlorides, sulfates and phosphates [27].

The benefits of including nopal in human diets are primarily related to the Ca content which is present and contributes to maintaining healthy strong bones. Although many vegetables are important sources of Ca, for example soy, spinach, grains and chard, nopal appear to be a better source of the mineral Ca due to their elevated content [5,23]. Phosphorous content in the diet is thought to be the second most important mineral in the formation of bone. Even though phosphorous levels are low in nopal powders, in general some grains like legumes contribute a substantial amount of this mineral [7].

Data suggest that the best age to harvest and consume are 135 days old, for their elevated calcium content. Furthermore, results also indicate that the nopal is rich sources of nutriment and can be used for medicines and cosmetics. Nopal have potential applications in the prevention and treatment of diseases such as osteoporosis, due its Ca content and for diabetes treatment due to the fiber content, because the evidence of medicinal properties for the nopal and also for the cosmetic consistency based in the fiber composition. Because this study showed that nopal is a significant source of fiber [19,20]. Related to the fact that nutritional deficiencies are currently widespread in many poor areas of the world most especially among the children in the developing countries, attention, therefore, must be focused on the inexpensive solutions, such as nopal powders, in order to take advantage of its production period. Nopal powders can be an economic alternative when used as supplement throughout all seasons without the production of fresh nopal. The dried products represent certain advantages for transport and preserving these products for prolonged periods in optimal conditions to ensure the nutritional quality and availability.

Nopal can be a rich source of soluble fiber during younger ages, and increased the insoluble fiber content at older ages. A noteworthy observation from this study is the proposal of increasing intake of older nopal powder in daily diets, related to the increased Ca content at advanced nopal age.

However, the authors believe that additional research is needed to understand more about the potential multiple applications in the processed foods for human consumption and pharmaceutical uses regarding the additional nutritional.

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