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# Physicochemical and Functional Properties of Cactus *'Opuntia ficus- indica L.'* Muller Flour: The Case of Cactus Fruit and Vegetable Flour

**Worku Batu[*1], Dawit Getahun[*2], Gebremicheal Abreha[*3]**
[*1]*Department of Chemistry, Ambo University, P.O.Box, 19, Ambo, Ethiopia.*
*E-mail worku.batu13@gmail.com.*
[*2] *Department of Plant Science, Adigrat University, P.O. Box, 50, Adigrat, Tigray, Ethiopia*
[*3] *Department of Chemistry, Adigrat University, P.O. Box, 50, Adigrat, Tigray, Ethiopia*


# Abstract

*This paper analyzed the physicochemical properties, functional properties and proximate composition of cactus tuna flour and cactus napolite flours prepared from cactus pear fruit–vegetable parts. Immature cactus fruit and leaf-vegetable parts were dried at 60°C, 70°C and 80°C. The cactus fruit 'tuna' and napolite parts of plants were dried and thoroughly milled into flour. The flours were analyzed for physicochemical properties, functional properties and proximate composition. The analyses showed no significant differences in crude protein, total lipid, crude fiber and total ash content in the flours. The results also revealed that napolite flour has higher moisture content and total solid 6.85% and 18.50%, respectively while tuna flour had higher ash (26.20%) and crude fiber (22.11%). The $P^H$ value of fresh fruit-vegetable was found to be between 6.20 – 6.65 while the flours $P^H$ value lies between 5.27 – 5.80. Functional properties for napolite flour showed water and oil holding capacity of 14.12 (60°C), 8.35 (70°C), 6.42 (80°C), and 2.02 (60°C), 2.01 (70°C), 2.02 (80°C) respectively. On the other hand, water and oil holding capacity of tuna flour were 16.24 (60°C), 10.21 (70°C), 7.12 (80°C), and 3.01 (60°C), 3.02 (70°C), 3.01 (80°C) respectively. At 60°C to 80°C a reduction of water holding capacity (54.3%) was observed in napolite flour, while 56.12% observed in tuna flour. The cladodes flours prepared at 60°C presented a higher quality regarding their nutritional and functional properties. Similarly, cactus fruit-vegetable flour had higher potential of water holding capacity and others functional properties. The physicochemical properties and functional properties of Cactus fruit – vegetable flour have good potential and nutritional value to service as flour.*


**Key words:** tuna, napolite, edible cactus, drying process, vegetable powder

# Introduction

Cactus pears are *Opuntia* genus plants of the *Cetaceous* family which are endemic in America (De La Rosa, H. J. Santana, A. D. El, 1998, Granados, S. D. El, 2003). This Cactus pear or prickly pear, a member of the Cactaceae family (Reyes Aguero JA, *et al*, 2005), originated from arid and semi-arid regions of Mexico, and was introduced into North Africa in the 16th century (Griffiths, P, 2004). Cactus pears were introduced into Ethiopia between1848-1920 (Tesfay Belay, *et al*., 2011). The plant is widely distributed in the arid and semi-arid regions of the country; especially in eastern and southern zones of Tigray Region of Ethiopia. Over the last few decades interest in cactus pear as food and feed has increased due to its drought resistance, high biomass yield, high palatability and tolerance to salinity (Tesfay Belay, *et al.*, 2011). Natural products and health foods had recently received a lot of attention both by health professionals and the common population for improving overall well-being, as well as in the prevention of diseases including cancer. In this line, different fruits and vegetables have been reevaluated and recognized as valuable sources of nutraceuticals (Jana S, 2012). The great number of potentially active nutrients and their multifunctional properties make cactus pear fruits and cladodes perfect for the production of health promoting food and supplements (Samia El-Safy F, 2013).

New economic strategy to increase utilization of cactus product similar to others grains and fruit vegetables; includes the production of cactus flour from the fruit when it is ripe and to incorporate the flour into various innovative products such as slowly digestible cookies, high-fibre bread and edible films is more interested (Aparicio-Saguilan, A., *et al.*, 2007), Juarez Garcia, E., *et al.*, 2006), Rungsinee, S. and Natcharee, P, 2007). Preparation of cactus flour can potentially offer new products of cactus, which is a use with standardized composition for various industrial and domestic uses. The particular interest to finding the cactus extract serve as food are the green pods (napolite), tuna (prickly pear fruit) and Peel of prickly pear fruit which are consumed as a source of food and nutrient in food (Jana, S, 2012 , Samia El-Safy. F, 2013). Freshly harvested Cactus pear cladodes are regarded as vegetables; they present a high content of water and a minor proportion of dietary fiber, lipids, and proteins, mineral, other antioxidants, and vitamins (Rodríguez-félix, A., Villegas-ochoa, M. A., 1997).

This plant is known for its medicinal properties, such as an auxiliary treatment for obesity, and gastrointestinal or cardiovascular disorders. These extracts also decrease the levels of cholesterol and serum glucose [OU, S. *et al.* 2001), Dukas, L., *et al.,* 2003).

The physiological effects on the human organism had been attributed to the functional properties that provide the dietary fiber (Sáenz, C. H., 1997; Sánchez-machado, D. I. *et al.,* 2004, Sáenz, C., 2000). Similarly, as fresh fruit-vegetables of cactus pears or *Opuntia* a genus plant was very important of food raw material; the flour which is the powder product of plants as the final product of milling had very important value in food. Cactus fruit and vegetables have a short shelf life, from 4-8 days, and consequently, it is sold fresh in the commercial market. Some options that offer added value to cactus pear cladodes are their use for the production of flours, soups, jams, dehydrated sheets and desserts (Kwok, B. H. L. *et al,* 2004). Identifying the physico-chemical properties of food and evaluating the functional properties of plant-flour helps to understand the quality of food raw materials.

## Cactus fruit-vegetable for source of food

The cactus pear fruit (Opuntia ficus indica) is associated with the semi-arid zones of the world; it is one of the few crops that can be cultivated in areas which offer very little growth possibility for common fruits and vegetables (Carmen Saenz, H., 1996). Commonly eaten fresh, it is known in some areas of the world as the 'bridge of life' because, during periods of little rain, it is one of the only crops that can be used as human food and cattle feed. Cactus fresh fruit has a similar composition to other fruits and vegetables. The prickly pear cactus plant is a fruit and the green pods is vegetable (Barbera, G., *et al.*, 1992). The green pods (pads), called napolite, are the vegetable and the red colored pear (tuna) of the cactus is the fruit. The green pods are edible all year round; however, the pears are highly available in the summer months.

Figure 1. Green and yellow tunas fruit and tuna flour

Figure 2. Cactus napolite and Napolite flour

Cactus Nopales; which are consumed as vegetable and its modified leaves (paddles) have many vital phytochemicals, fiber, anti-oxidants, vitamins, and minerals that can immensely benefit health. The succulent paddles are rich sources of dietary fiber, especially non-carbohydrate polysaccharides, such as pectin, mucilage and hemicellulose (Salvador, A., *et al*., 2007). This rich fiber and mucilaginous content aid in smooth passage of digested food particles through the gut and relieve constipation condition.

## Cactus fruit and vegetable for source of food in northern parts of Ethiopia

Cactus pear is a strategic crop in many parts of Tigray Region. Human consumption, animal feed, farm and homestead fencing income source, fuel wood, soil and water conservation, and all jointly were identified as major purposes of cactus growing in Tigray. It renders livelihood sources for small farmers and local traders and has great contribution to food security for many people of the region during the period from June to September. Prickly pear fruit was usually eaten fresh commodity by population of surrounding area, in Eastern Zone of Tigray.

Even if it requires transporting for markets or for population far from source, it was transported as its fresh, without convert into simply, easy and increase shelf-life. Especially transportation of fruit as fresh consumes costly, shortage of life and easily expires in two or three days. But still there is no any practice and application method to store cactus product similar to other foods, like Sweet potato flour [Rodrı´guez-Ambriz, *et.al*., (2008)], mango pulp flour (OU, S. 2001), or wheat flour (Srivastava S, *et al.,* 2012) store for long period of time. In fact of that, this investigation, the method of excess fruit were dried, converted into flour and stored for year rather than based on seasonal were investigated and their physicochemical; function properties of product, acceptability of flour were analyzed (Okaka, J. C. and Potter, N. N. 1977). Functional properties (solubility, foam ability, gelation and emulsification properties) are the intrinsic physicochemical characteristics which may affect the behaviour of food systems during processing and storage. Adequate knowledge of these physicochemical properties indicates the usefulness and acceptability for industrial and consumption purpose. Previous studies on physicochemical properties have focused on flours of protein-rich seeds (Sáenz, C., *et al*. 2002).

## Fruit-vegetables flour and their functional properties

Flour is a powder which is made by grinding cereal grains, beans, or other seeds or roots (like cassava) (Sompong, R., *et al.,* 2011). It is the main ingredient of bread, which is a staple food for many cultures, making the availability of adequate supplies of flour a major economic and political issue at various times throughout history. Example; wheat flour is one of the most important ingredients in European, North American, Middle Eastern, Indian and North African cultures, and is the defining ingredient in most of their styles of breads and pastries. Rye flour is an important constituent of bread in much of central Europe, and rice can also be used in flour. Banana pulp and peel flour, potato flour is one of the most available vegetable flour on the market. The use of processed cactus pears and cladodes by the food industry is very low in the majority of the producing countries, except in Mexico, the fruit is consumed mainly as a fresh commodity (Sompong, R., *et al.,* 2011). Considering cactus fruit (tuna) and vegetable (napolite), most studies indicated that the medicinal value of cactus is similar to other food plants such as potato, banana, mango or wheat product (Srivastava S, *et al.*, 2012, Rodríguez-félix, A., Villegas-ochoa, M. A. 1997)). However, these studies had limitations in solving problems related to shelf-life of cactus products as flour; the previous studies also did not address the physicochemical properties, functional properties and proximate composition of Cactus flour. As a result, the present study intended to analyze the physicochemical properties, functional properties and proximate composition of Cactus pear fruit and vegetable flours obtained from cactus pear cladodes.

# Materials and Methods

## Description of study area

Cactus raw materials for the present study were collected from agricultural farm lands in Erob and Gulomekeda districts, Tigray regional state, Ethiopia. Gulomekeda district is located at 918km from Addis Ababa and 135km from Mekelle, the capital city of Tigray regional state. Irob district is located in the eastern zone of Tigray region; 938km far from Addis Ababa and 155km from Mekelle city. Local farmlands that contain available fresh cactus fruit and vegetable were considered for the study.

## Preparation of cactus fruit (Tuna) and vegetable (Napolite) flour

Two stages of the most common Cactus stages, namely deep green (1st age) and yellowish green (2$^{nd}$ age) for vegetable 'napolite' flour preparations and yellowish green (1$^{st}$ age) and yellow with green tip (2$^{nd}$ age) for fruit 'tuna' flour preparations, were collected from different farmlands, around eastern zone, Tigray. A total of 8-12kg each stage; plants parts (napolite and fruit) of each age were obtained from agricultural farmlands. The Cactus Fruit (tuna) and Vegetables (Napolite) were washed and separated into pulp and peel. To reduce enzymic browning, the samples were then dipped in 0.5% (w/v) citric acid solution for 10 min, drained and dried in an oven (AFOS Mini Kiln, at 60$^{o}$C, 70$^{o}$C, 80$^{o}$C overnight). The dried samples were ground in a Grinding Mill Laboratory to pass through 40 mesh screen to obtain plants flour. The yield of flour is calculated by dividing the amount of flour produced by the amount of fresh cactus sample used, and the result converted to 162.7g/Kg (g of flour/Kg of cactus). All plants flour's were stored in airtight plastic packs in cold storage (15±2$^{o}$C) for further analyses. The physicochemical analyses were applied to know the acceptability of flour.

## Physicochemical characterization of flour

## PH, TSS and viscosity

The pH of the flour was measured using a Coming pH meter, model 10. Flour suspension (8% w/v) was stirred for 5 min, allowed to stand for 30 min, filtered and the P$^{H}$ of filtrate measured (López-Cervantes, 2011).Total soluble solids (TSS) in the same flour slurries were measured using an Atago refractometer (Atago PAL-1, Co. Ltd., Tokyo, Japan) (Salvador, A., *et al*., 2007). Viscosity was determined as described by Fagbemi, Okaka, J. C. and Potter, N. N. (1977). Flour was dispersed in water at 8% (w/v) concentration using a magnetic stirrer (1000 rpm) and heated from 30 to 95°C in a shaking water bath and kept at this temperature for 20 min. The slurry obtained was stirred constantly and cooled at room temperature. The viscosity was measured using a Vibro-Viscometer (SV-10).

## Determination of amylose content and starch content

Determination of amylose content

Amylose content was determined according to the procedure specified in Fateatum Noor, (2014) method with some modification. Cactus flour, powder (0.02g) was taken into a volumetric flask. Then 0.2ml of ethanol (95%) following by 1.8ml of 1N NaOH was added and made 20ml total volume by adding distilled water. It was kept 20min. at room temperature and boiled for 10min at 45°C. It was filtered using Whatman filter paper (540). Then 1ml filtrate was transfer to a 50ml tube and 0.2ml of 1M acetic acid and 0.4ml Lugol's solution were added and made total volume 20ml by added distilled water. The mixture was mixed and kept for 20min at room temperature. Then the absorbance was taken at 620nm. The Amylose content was determined using potato Amylose standard curve.

Determination of starch content

The starch content was determined by the standard procedure method AOAC. (1990). Five gram of Cactus flour, powder was placed in a beaker and mixed with 30ml of water before transferring to the water bath and heated at 60°C for 25min. Then 100ml of 95% ethanol was added to it and stirred by magnetic stirrer for 15min. It was filtered through Whatman filter paper no.2. The residue was soaked in 50% ethanol solution for 1hr after which the residue was washed on the filter paper with 50% ethanol solution for 4hr. The residue was collected into a round bottom flask and 100ml of water and 20ml of HCl added to it. The flask was attached with the condenser and heated for 2.5hr. Then it was allowed to cool and neutralized by added NaOH solution (40%). After that 10ml of Fehling solution was taken into a conical flask and titrated against neutralized sample solution. When copper sulfate like color observed, then 3drops of methylene blue indicator was added and continue titration. The end point was indicated by a brick red color.

## Determination of proximate composition of the flours

Moisture was assessed on subjecting the cactus flour to 100°C in an incubator to attain constant weight and the difference in initial and final weight of floor was expressed as percentage moisture. The crude protein content (N×6.25) was

determined by micro-kjeldahl method Marimuthu, M. and Gurumoorthi P. (2013). Crude lipid, crude fiber and ash contents were detected on employing AOAC methods Marimuthu, M. and Gurumoorthi P. (2013). Crude carbohydrate was calculate as outline by Total crude carbohydrates (%) = 100-(Crude protein + Crude lipid + Ash).
Evaluation and functional properties of the flours

Bulk density, least gelation concentration, emulsion activity and emulsion stability was determined by the standard methods (Maldonado, R. J.; Pacheco-delahaye, E. 2003). Water and Oil absorption capacities of flours (as is basis) was determined at room temperature following the method of (Maldonado, R. J.; Pacheco-delahaye, E. 2003, Rodríguez-félix, A., Villegas-ochoa, M. A. 1997), specified in literature review.

Foaming capacity (FC) and Foam stability (FS) were also measured by the method of Okaka, J. C. and Potter, N. N. (1977). The volume of foam at 30sec of whipping was expressed as FC. The volume of Foam was record one hour after whipping to determine FS as percent of the initial foam volume.

### Swelling capacity

The method of Okaka and Potter (1977) with some modifications was used for determining the swelling capacity. The sample was filled up to 10ml mark in a 100ml graduated cylinder and water added to adjust total volume to 50ml. The top of the graduate cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 minutes and allow to stand for another 30 minutes. The volume occupies by the sample was then recorded after 30 minutes (Srivastava S, *et al.*, 2012).

## Results and Discussion

### Cactus Fruit (Tuna) and Vegetable (Napolite) flour characteristics

The study showed that fresh Cactus pear 'napolite' has high moisture content, 91.27g.100 $g^{-1}$, while the fresh cactus fruit 'tuna' had 86.28g.100$g^{-1}$. The proximal composition of fresh fruit-vegetable; fresh cactus fruit 'tuna' content TSS (13.60 Brix), TS (13.73%), and ash (2.62%), while Fresh Cactus vegetable 'napolite' contained TSS (12.6Brix), TS (12.82%) and ash (2.96%). The $P^H$ value of fresh-vegetable 'napolite' was 6.65 and higher than fresh fruit 'tuna' with a value 6.20. The moisture content of both fresh fruit 'tuna' and napolite were found to be greater than moisture content of fresh sweet potato as reported by (Rodrı´guez-Ambriz, *et al.*, 2008), banana peel (Rodríguez-félix, A., Villegas-ochoa, M. A. 1997). One of the factors that affect the shelf-life of cactus pear fruit and napolite after harvest was the content of high moisture in fruit and vegetable of plant product.

The drying times at 60°C, 70°C and 80°C were 10 hours, 7hours and 4 hours, respectively. These results confirmed that drying at 80°C improved the mass transfer and velocity of drying and also eliminated the period required for constant drying (Carmen Saenz H. 1996, Rodríguez-Garcia, M. E., 2007). Cactus napolite and tuna showed long drying times in relation to the drying times of other vegetables, such as sweet potato, banana peel, cauliflower and broccoli. This could be attributed to the impermeable cuticle on the surface of the cactus pear cladodes that function to prevent water evaporation.

## Determination of proximate composition of flours`

The result of proximal analysis for Fruit-vegetable flour is presented in Table (1). The result showed non-significant differences ($p \leq 0.05$) in protein, lipids, crude fiber and ash contents in the napolite flours and fruit 'tuna' flours along the variation of drying temperatures. During the preparation of dietary supplements, it is important to consider the maturity of the cactus pear napolite flour. The colour of plants were give the information on the fruit vegetable age; namely deep green (1st age) and yellowish green, (2nd age) for vegetable 'and while yellowish green (1st age) and yellow with green tip (2nd age) for fruit 'tuna' flour preparations considered during sampling process.

Young cactus pear napolite are nutritionally superior to the more mature ones (Rosado, J. L. and Díaz, M. 1995). For that reason, the cactus pear napolite in the study were cut into 10 ± 5 cm pieces, with a weight between 200 g to 250 g. In general, the crude protein, total lipid, crude fiber and total ash contents of the napolite flours, reported in this study, were similar to the information reported by Rodríguez-García, *et al.* (2007) in cactus pear cladodes flours, while tuna flours showed significantly different values. The variations presented in the previous studies can be a consequence of factors such as the variety, state of maturity and growing conditions of the vegetable. The chemical composition showed minimum differences when compared to the values reported for flours of other vegetable byproducts, such as carrot peel (Alvani, K., *et al.*, 2011).

Table 1. Proximate analysis of cactus pear fruit-vegetable flours g.100 $g^{-1}$ dry weight

| Analysis | Napolite (Vegetable) | | | | Tuna ( Fruit) | | | |
|---|---|---|---|---|---|---|---|---|
| | Fresh-vegetable | Drying Temperature | | | Fresh-Fruit | Drying temperature | | |
| | | 60°C | 70 °C | 80 °C | | 60 °C | 70 °C | 80 °C |
| Moisture (%) | 91.27 | 6.85 | 6.91 | 6.88 | 86.28 | 6.12 | 6.01 | 5.98 |
| TSS (Brix) | 12.6 | 4.1 | 4.21 | 4.16 | 13.60 | 3.46 | 2.8 | 2.9 |
| TS (%) | 12.82 | 18.5 | 16.78 | 15.92 | 13.73 | 3.52 | 3.0 | 2.26 |
| PH value | 6.65 | 5.27 | 5.38 | 5.35 | 6.20 | 5.58 | 5.53 | 5.80 |
| Ash content (%) | 2.96 | 20.2± 0.2 | 20.12± 0.3 | 20.68± 0.12 | 2.62± 0.2 | 26.2± 0.2 | 26.4±0.2 | 26.52± 0.2 |
| Crude protein (%) | - | 7.45 | 7.41 | 7.24 | - | 8.21 | 8.01 | 8.00 |
| Crude lipid (%) | - | 2.30± 0.23 | 2.31± 0.12 | 2.38± 0.1 | - | 3.10 | 3.00 | 2.88 |
| Crude fiber (%) | - | 20.46 | 20.12 | 20.78 | - | 22.11 | 22.04 | 21.86 |

The moisture content of all Cactus flours prepared from napolite and tuna at different drying temperature varied between 5.98%, to 6.91%. The highest (6.91%) moisture content was found in napolite flour whereas lowest (5.98%) moisture content was found in 'tuna 'flour. These values also were consistent with Juarez-Garcia, E., *et al*., (2006), who observed that the moisture content of Cactus pear cladodes flour was 6.78%.

The protein content of Cactus fruit 'tuna flour' varied between 8.00 – 8.21% at a drying temperature of 60°C, 70°C, and 80°C. Similarly that of Cactus pear napolite flour was between 7.24%- 7.45%. Highest (8.21%) protein content was observed at a drying temperature 60°C for tuna flour, while for napolite flour it was 7.45%. Significant differences were observed in protein content in napolite flour and tuna flour at different drying temperature. The crude protein content napolite flour was lower than those obtained in tuna flour.

The protein content napolite flour and tuna flour were greater than those obtained by Juarez-Garcia, E., *et al*., (2006) who reported in the protein value of Cactus pear cladodes flour was 7.26%. These values were similar to Juarez-Garcia, E., *et al*., (2006) who reported that the crude protein content of Cactus pear cladodes flour was 7.24 – 7.52%. These results were much higher than the crude fiber that reported by Juarez-Garcia, E., *et al*., (2006) for cactus pear cladodes flour (18.468%). The variation of protein content could be due to maturation of the fruit –vegetables and environmental conditions. The protein content of napolite flour (7.24– 7.45%) and tuna flour (8.00 – 8.25%) reported in this investigation were higher than the protein content of cladodes flour (7.260%) reported by Juarez-Garcia, E., *et al*., (2006) in and had compromise with the values reported for different species of the genus Opuntia (Griffiths, P. 2004).

Crude lipid of napolite flour (2.30 - 2.38%) and tuna flour (2.98 – 3.10%) were similar to the finding of Moreno Álvarez, M. J. (2009) for cladodes of the same species, a difference which may be attributed to the different climatic conditions where harvesting was done. Napolite flour content dietary fiber (20.46% - 20.78%) and tuna flour content of dietary fiber (21.86 – 22.11%) observed in this studied were have good compromise with the value reported for different species of the genus Opuntia (Griffiths, P. 2004). Cactus fruit-vegetable flour is a good source of total dietary fiber being 20.78 – 22.11% (on dry weight basis). The ash content of different parts of Opuntia flour at different drying agent; Cactus pear napolite flours and Cactus fruit tuna flours were 20.2% - 20.68% for napolite and 26.2% - 26.52% for tuna flours as results. There were no significant differences among different varieties of Opuntia species (Askar, A. and El-Samahy, S.K. 1981, Salvador, A., *et al*., 2007) reported that the ash content of cladode flour was

20.24% – 20.78% which the good agreement with the present study are. The variation in ash content in different varieties cactus fruit-vegetable flour might be due to the locality. As shown in Table (1), the total soluble solids (TSS) and total solids contents (TS) were recorded both for fresh fruit-vegetable of cactus pears and for flour prepared from fruit-vegetable at different drying temperature on the basis of weight. Cactus pear fruit 'tuna flour' contained of TSS, crude protein, lipid, fiber and ash amounts higher than napolite flour.

## Physicochemical characterization of flour

The physicochemical properties of Cactus fruit-vegetable flour, extracted starch from Napolite flour and tuna flour by distilled water is presented in table 2.

Table 2. Physicochemical properties of napolite and tuna flour at different drying temperatures

| Analysis | Napolite (Vegetable flour) | | | Tuna ( Fruit flour) | | |
|---|---|---|---|---|---|---|
| | Drying Temperature | | | Drying temperature | | |
| | 60°C | 70 °C | 80 °C | 60 °C | 70 °C | 80 °C |
| Amylose content | 25.12 | 24.98 | 24.96 | 28.87 | 28.66 | 28.75 |
| Starch content | 67.20 | 67.01 | 66.43 | 86.02 | 85.41 | 84.47 |
| Least- gelation capacity (%) | 1.75% | 1.75 | 1.74 | 1.98 | 1.96 | 1.98 |

Amylose contents observed in napolite flour samples ranged from 25.12% to 24.96% at different drying agent, while 28.75% - 28.87% recorded in fruit 'tuna' flour. Tuna flour had higher amylose content than napolite flour. The value was higher than that found in the amylose content of jackfruit seed flour (26.57%) (Tulyathan, V., *et al*., 2002), and higher than the amylose content in potato starch (Saenz, C.H., 1997) who observed the amylose content of potato starch flour was (25.2%). Similarly starch contents observed in napolite flour samples ranged from 66.43% to 67.20%. Tuna flour had higher starch content than napolite flour. The variation in amylose content and starch content of cactus fruit-vegetable flour might be due to use different species and growing condition (Tulyathan, *et al*, 2002). The gelation capacity of napolite flour was 1.75% while it was 1.98% for Tuna flour. This indicates that cactus fruit-vegetable flour were more favorable and needed to form a gel with others flour those have low gelation capacity because of their low gelation capacity. Variations in the gelling properties of different flours may be due to variations in the ratio of different constituents such as carbohydrates, lipids and proteins that make up the flours.

## Evaluation and functional properties of the flours

Water and Oil holding Capacity**:** Data of the water and oil absorption are embodied in Table (3). The water holding capacity (g/ g) of napolite flours at different drying temperature; 60ᵒC, 70ᵒC, and 80ᵒC were 14.12, 8.35, and 6.42 respectively. The values obtained at 60ᵒC, and 70ᵒC, were higher than that observed by Rosado, J. L. and Díaz, M. (1995) of 11.1 g/g in dehydrated nopal and 7.1 g/g in an extract of nopal fiber.

Table 3. Functional properties of WHC, OHC and Swelling power of Napolite and Tuna flour

| Analysis | Napolite (Vegetable flour) | | | Tuna ( Fruit flour) | | |
|---|---|---|---|---|---|---|
| | Drying Temperature | | | Drying temperature | | |
| | 60ᵒC | 70 ᵒC | 80 ᵒC | 60 ᵒC | 70 ᵒC | 80 ᵒC |
| Water holding capacity (%) | 14.12 | 8.35 | 6.42 | 16.24 | 10.21 | 7,12 |
| Oil holding capacity (%) | 2.02 | 2.01 | 2.02 | 3.01 | 3.02 | 3.01 |
| Swelling power (g/g) | 5.67 | 6.10 | 6.23 | 6.96 | 7.02 | 7.42 |

Key: WHC (g of water/g of dry weight of sample of flour), OHC (g of oil/g of dry weight of sample flour)

These differences can probably be attributed to differences in the raw material used. However, the water absorption capacity of cladodes flour was quite high compared to other vegetable proteins (1.38 g $H_2O$/g peach kernel flour) (Aremu, M.O., *et al.*, 2007. Sáenz, C. 2000), prepared cactus pear cladodes flours from old cladodes (1-3 years of age) yielding a water holding capacity of 5.6 g water/g dry weight. Moreover, the oil holding capacity (g/g) of napolite flours at different drying temperature of 60ᵒC, 70ᵒC, and 80ᵒC were 2.02, 2.01, and 2.02 respectively. Rosado, J. L. and Díaz, M. (1995) reported an oil holding capacity of 3.7 g of oil /g of dry weight in cactus pear cladodes flours. The differences in the values of the oil holding capacity when compared to those reported by different authors, can be attributed to variety and age of cladodes, degree of milling and the drying conditions (Askar, A. and El-Samahy, S.K. 1981). Due to its high water holding values, the cactus pear fruit-vegetable flour could be appropriate to improve texture in a variety of foods such as bakery products or desserts (Askar, A. and El-Samahy, S.K. 1981).

Water holding capacity

The water holding capacity of cactus pear napolite and tuna flours are shown in Figure 1. The flours prepared in this study showed a high water holding capacity, ranging from 6.42 to 14.12 g water/g dry sample. During the drying process at 70°C and 80°C, the water holding capacity decreased to 43% and 55%, respectively, with respect to the drying process at 60°C. Moreover, in the flours produced at 80 °C, there was a decrease in the content of mucilage (information not shown). The results above are similar to those obtained by Lobato, Martínez and Chávez (2004). During the drying of cactus pear in a conventional oven, they reported water holding capacity of 10.03 g of water/g dry weight in the flours prepared at 50°C and of 4.4 g of water/g of dry weight in the flours obtained at 80°C. In addition, in the cactus pear cladodes flours (young cladodes) grown by Rosado and Diaz (1995), the water holding capacity was 11.1 g water/g of dry weight and Sáenz (1997) prepared cactus pear cladodes flours from old cladodes (1-3 years of age) yielding a water holding capacity of 5.6 g water/g dry weight, a value that is minimal compared to that obtained in this study.

## Oil holding capacity

The oil holding capacity is an important parameter used to evaluate the hydrophobic nature of particles that constitute the fiber fraction, which is related to the emulsifying properties.

There were no significant differences ($p \leq 0.05$) in the oil holding capacity of the cactus pear cladodes flours formed at 60°C, 70°C and 80°C (Figure 1). In addition, Rosado and Diaz (1995) reported an oil holding capacity of 3.7 g of oil/g of dry weight in cactus pear cladodes flours. The differences in the values of the oil holding capacity of this work, in comparison to those reported by other authors, can be attributed to the variety and age of cladodes, the degree of milling of the flours and the drying conditions. The cactus pear cladodes flours prepared in this study had a lower oil holding capacity and, as consequence, unsuitable emulsifying properties.

## Swelling power

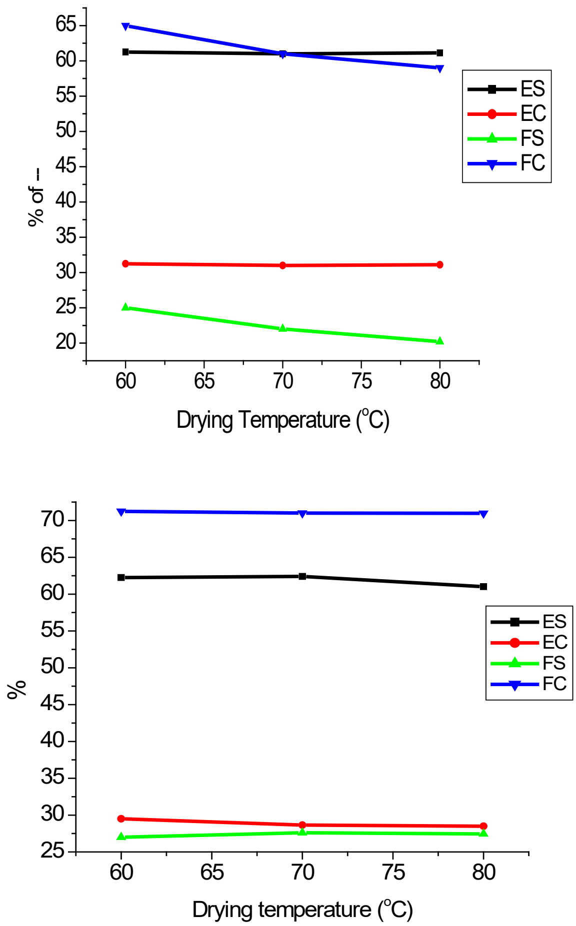
Swelling measures the hydration capacity of a power. This is because the swelling power measures the weight of swollen starch granules and their occluded water. This measure is important because food eating quality is often connected with retention of water in the swollen starch granules (Sáenz, C., *et al*. 2002). In this study, the result showed that the swelling power of napolite flour was between 5.67 -6.23 g/g, while that of fruit tuna flour was 6.96 -7.42g/g. The result was similar with that reported by Samia Elsafy. F, (2013) for cladodes flour (6.0 g/g).

Table 4. Functional property levels of cactus napolite and tuna flour

| Analysis | Napolite (Vegetable flour) | | | Tuna (Fruit flour) | | |
|---|---|---|---|---|---|---|
| | Drying Temperature | | | Drying temperature | | |
| | 60°C | 70 °C | 80 °C | 60 °C | 70 °C | 80 °C |
| Emulsion Stability (%) | 61.25 | 61.00 | 61.12 | 62.12 | 62.41 | 62.01 |
| Emulsion capacity (%) | 31.25 | 31.00 | 31.10 | 29.5 | 28.65 | 28.5 |
| Foam stability (%) | 15 | 16.01 | 16.21 | 17.00 | 17.60 | 17.45 |
| Foam Capacity (%) | 65 | 61.00 | 61.01 | 71.25 | 71.01 | 70.98 |
| Viscosity (B.U) | 19.64 | 20.10 | 18.90 | 24.02 | 24.00 | 24.00 |
| Bulky density (g/cm$^3$) | 0.42 | 0.43 | 0.413 | 2.21 | 2.10 | 2.01 |

For all Cacti fruit-vegetable flour the mean viscosity ranged between 18.90 - 24.02 B.U; at different drying temperature. The level of Viscosity in napolite flours (18.90 – 19.64 B.U), while 24.00 – 24.02 B.U in tuna flour. Emulsion capacity results revealed that Napolite flour had 31.25% to 31.10% and that for tuna flour had 28.5% to 29.5%, which was higher than that of Wheat flour (14.68%). Emulsion properties play a significant role in many food system where the protein have the ability to bind fat such as in meet products batter, dough and salad dressing. Bulk density value for Napolite flour was 0.413- 0.42 g/cm$^3$ while Tuna flour recorded 2.01 -2.21 g/cm$^3$.

Bulk density is generally affected by the particle size and density of the flour and it is very important in determining the packaging requirement, material handling and application in wet processing in the food industry.




a) Napolite flour b) Tuna flour

Figure 3. Emulsion and foaming properties of napolite and tuna flours

## Flours Comparison

Table 5. Proximate composition of Cactus pear Fruit-vegetable flour comparison with other fruit-vegetable flour studied in literature reviews

| Constituent | Napolite flour | Tuna flour | Cladode flour | Brown rice flour | Jack bean flour | Wheat flour | Banana flour |
|---|---|---|---|---|---|---|---|
| Moisture content | 6.85 | 6.12 | 6.79[c] | 9.61[e] | 5.73[d] | 12.98[e] | |
| TSS | 4.1 | 3.46 | 4.1[c] | - | - | - | 3.46[f] |
| P[H] value | 5.27 | 5.58 | 6.27[c] | - | - | 6.01[b] | 5.47[f] |
| Ash content | 20.2 | 26.2 | 20.46[a] | 1.77[e] | 2.11[d] | 1.40[e] | 2.7[f] |
| Crude protein | 7.45 | 8.21 | 7.52[a] | 8.50[e] | 24.32[d] | 12.58[e] | 4.33[f] |
| Crude Lipid | 2.30 | 3.10 | 2.34[a] | 2.80[e] | 3.17[d] | 1.80[e] | 0.71[f] |
| Dietary fiber | 20.46 | 22.11 | 6.15[a] | 1.23[e] | 6.13[d] | 0.85[e] | 15.52[f] |
| Carbohydrate | | | 68.09[a] | 77.31[e] | 41.26[d] | 71.23[e] | 83.94[f] |

**Source:** a) Lopez-Cervantes *et al*. (2011), b). Adeleke, R.O. and Odedesi. J.O. (2010), c). M. Marimuthu and P. Gurumoorthi. (2013), d). Islam *et al,* (2012), e). Bezera C.V, *et al* (2013). f). Abbas F.M. *et al* (2010)

The above table shows that the proximate composition of napolite flour studied under this investigation; moisture content (6.85%), TSS (4.1%), ash content (20.2%), lipid (2.30%) were similar with the proximate composition observed in cladode flour by Lopez Cervantes *et al* (2011), Rosado and Diaz (1995), who reported the moisture content (6.79%), TSS(4.1%), ash content (20.46%) and crude lipid (2.34%). But the values of proximate composition recorded in tuna flour were higher than those observed in napolite flour reported in this investigation and cladodes flour reported by Lopez Cervantes *et al*, (2011).

The dietary fiber content of both napolite flour (20.46%) and tuna flour (22.11%) are higher than those reported for brown rice flour (1.23%), jack bean (6.13%) and banana flour (15.52%). The proximate composition of cactus pear napolite flour, cactus tuna and cladodes flours showed poor level of protein content (6.85 – 6.785%), when compared to the values reported for flours of other vegetable by products, such as Jack-bean flour (24.32), reported by M. Marimuthu and P. Gurumoorthi. (2013), wheat flour (12.58%) and Brown rice (8.50%) reported by Islam *et al.* (2012).

Table 6. Functional properties of Cactus pear Fruit-vegetable flour and comparison with other fruit-vegetable flour

| Constituent | Napolite flour | Tuna flour | Cladode flour | Banana flour (unpeeled) |
|---|---|---|---|---|
| WHC | 14.12(60°C)<br>8.35(70°C)<br>6.42(80°C) | 16.24(60°C)<br>10.21(70°C)<br>7.12(80°C) | 14.44(60°C)[a]<br>8.48(70°C)[a]<br>6.48(80°C)[a] | 6.10(40°C)[g]<br>6.34(70°C)[g]<br>8.19(80°C)[g] |
| OHC | 2.02(60°C)<br>2.01(70°C)<br>2.02(80°C) | 3.01(60°C)<br>3.02(70°C)<br>3.01(80°C) | 2.02(60°C)[a]<br>2.01(70°C)[a]<br>2.02(80°C)[a] | 0.93(40°C)[g]<br>0.98(60°C)[g]<br>1.28(80°C)[g] |
| Swelling Power (g/g) | 5.67 - 6.23 | 6.96 – 7.24 | 5.1 -6.9[h] | - |

Source :a) Lopez-Cervantes et al. (2011), g) Samia El -Safy.F. (2013)

The differences in the values of the water and oil holding capacity of other vegetable flour in comparison to this study at different drying temperature can be attributed to the quality and functional properties of vegetable flour level, the degree of milling of the flours and the drying conditions (Askar, A. and El-Samahy, S.K. 1981).

The water holding capacity and oil holding capacity of cactus flours had a good potential than banana flour (Abbas *et al.,* 2010). Due to its high water holding values, the cactus pear fruit-vegetable flour could be appropriate to improve texture in a variety of foods such as bakery products or desserts (Askar, A. and El-Samahy, S.K. 1981).

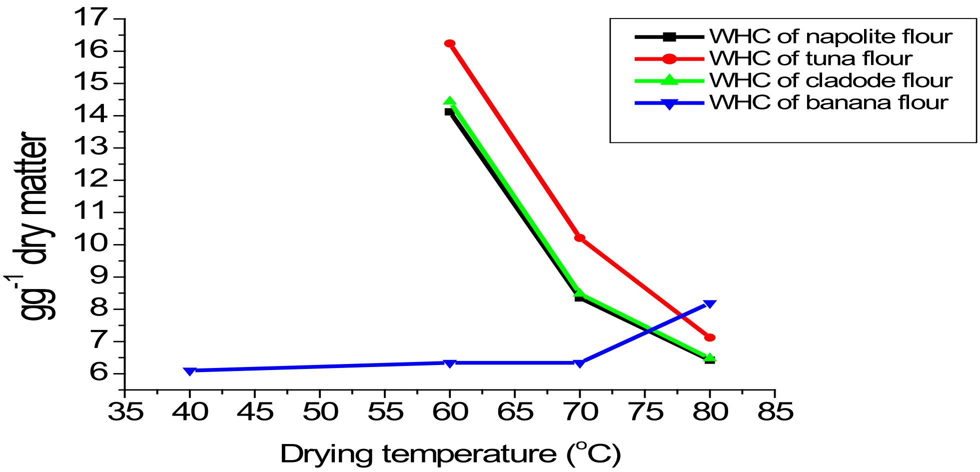



Figure 4. Functional properties of cactus fruit-vegetable flour and other flours at different drying temperatures

The functional properties observed in figure 2 at different drying temperature in this study and reported by another authors have a good compromise together. Especially, the proximate composition value recorded in this study was similarly with the proximate composition observed in cladodes flour reported by Lopez Cervantes *et al.* (2011).

## Conclusion

The present study revealed that the cactus fruit – vegetable flours processed at 60 °C are considered the most adequate for the formulation of dietary supplements. The drying process used did not alter the values of resistant starch, guaranteeing the same content when compared to the natural raw material. The application of high thermal treatments during the preparation of cactus' tuna flours and napolite flour affect the water absorption capacity (functional property). The study showed that the functional properties of cactus fruit-vegetable flours possess high water and oil absorption capacities. The foaming capacity and stability in the flours were found to be higher than for most other vegetable flours. This implies that the cactus flour could serve as a potential replacement of known proteins in food applications requiring high foam ability and stability.

Finally, the high emulsion activity and stability of the napolite and tuna flours indicates that they could be used as ingredients in many food formulations such as salad dressing, comminuted meats, ice creams, cake batters and mayonnaise.

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