

## Nutrient and phytochemical content, anti-oxidant activities and functional properties of Cactus pear (*Opuntia ficus indica*) seeds grown in Tigray, Ethiopia

Tewelde Hailemichael<sup>1</sup>, Muluberhan Kasaye<sup>1</sup> and Kelbessa Urga<sup>2\*</sup>

<sup>1</sup>Center For Food Science and Nutrition, College of Natural and Computational Sciences, Addis Ababa, University, P.O. Box, Addis Ababa, Ethiopia

<sup>2</sup>Ethiopian Public Health Institute, P.O. Box 1242, Addis Ababa, Ethiopia

\*Corresponding author: kelbessau@yahoo.com

### Abstract

**Background:** Cactus pear (*Opuntia ficus-indica*) seed is one of the main components of fruit crops which are tightly packed together in a mucilaginous structure inside the endocarp of the fruit.

**Objective:** The study was carried out to investigate the nutritional composition, anti-nutritional factors, anti-oxidant activities and functional properties of cactus pear seeds collected from Tigray region.

**Methods:** Standard analytical methods were used to analyze nutritional composition, antinutritional factors, anti-oxidant activities and functional properties of cactus pear seeds.

**Results:** Average values for moisture, crude protein, crude fat, crude fiber, total ash, carbohydrate and gross energy were 4.17g/100g, 10g/100g, 10.50g/100g, 18.23g/100g, 1.63g/100g, 55.47g/100g and 392.84cal on dry weight basis, respectively. The contents of Ca, K, P, Fe, and Zn content of the samples were 390.14mg/100g, 446.46mg/100g, 206.18mg/100g, 4.37mg/100g, and 2.01mg/100g, respectively. High phytate (259.20mg/100g), low tannin (0.13mg/100g) and oxalate (0.11mg/100g) contents were observed. The methanolic extract of the seed exhibited anti-oxidant capacity ranging from 43 to 95% of inhibition. With regard to functional properties seed flour, high value of water solubility index (5.6g/100g) and low value of bulk density (0.80g/ml) on dry fresh weight basis were observed. Ambasha, traditional fermented flat bread prepared from 95% wheat flour and 5% cactus pear seed flour was highly accepted by panelists compared with other ratios.

**Conclusion:** This study demonstrated that cactus pear seeds can be used as supplement to cereal-based foods consumed in rural areas.

**Key words:** Cactus seeds, functional foods, phytochemicals, sensory evaluation

### Introduction

Cactus pear (*Opuntia ficus-indica*) is commonly known as “prickly pear” and grouped under the Cactaceae family (Singh 2003). There are nearly 1500 species of cactus belonging to the *Opuntia* genus among which cactus pear is the most well-known species. Cactus pear is well adapted to grow wild in arid and semi arid regions, where the production of more succulent food plants is severely limited. The ability to adapt to arid conditions is associated with the shape of its several organs and its Crassulacean acid metabolism (CAM). The CAM plants take up CO<sub>2</sub> primarily at night, leading to high water-use efficiency and high drought resistance. Most Cactus pears are widely distributed in Europe, Southwestern United States, much of Latin America, South Africa and the Mediterranean countries (Nobel 1988). Cactus pear is locally known as Beles and was introduced to Tigray, Ethiopia between 1848 and 1870 by a Catholic priest Abune Yakob. Currently, cactus pear is widely spread throughout Tigray region and is believed to cover more than 379,338 hectares of land, i.e., 7.4% of the total land of Tigray region (Russell and Felker 1987). Cactus pear is considered as a ‘Bridge of life’ in Tigray area,

because of its importance as food for both humans and animals. During the summer season, many people especially shepherds do not require to eat their lunch because of their dependence on fruits of cactus pears. The fairly high sugar content and low acidity in the pulp render the fruits to be delicious and sweet and they become ripe during the months of July and October (Mondragón-Jacobo and Pérez-González 2001). Cactus pear fruit contains three main components namely: skin, pulp and seed. The cactus pears fruit can be eaten as fresh fruit or after processing in several ways. Due to the short shelf life the ripe fruits, they are usually processed into seed flour, juice and jam which can be consumed throughout the year (Felker and Guevara 2001). Studies conducted in different countries showed that cactus pear seed is nutritionally important. However, the use of cactus pear seed as food is unknown in Tigray, the study area. Surplus ripe fruits are discarded or fed to animals. The present study was designed to determine the nutritional composition, anti-nutritional factors, antioxidant capacity, and functional properties as well as evaluate the sensory acceptability of cactus pear seeds food products.

## Materials and methods

**Sample collection and preparation:** Ripened (yellowish color) cactus pears were randomly collected in October from Hatset Kebele, Ethiopia, and were washed and peeled using a stainless knife. The seeds were isolated by pressing the whole edible pulp and repeatedly washing the mucilage with water. Then, the seeds were covered with muslin cloth and dried in the sun. Dried seeds were decorticated using mortar and pistil to remove the sticky-remnant pulps and the seed coat, ground to powder, passed through 0.45mm sieve and kept in polyethylene bags at room temperature until analysis.

### Analytical Methods

**Proximate composition:** Moisture, crude protein (N x 6.25), crude fat, crude fiber and total ash content of cactus pear seeds were determined according to the AOAC official method (AOAC 2000), while carbohydrate content was determined by difference.

**Mineral content:** Zn and Fe contents were determined by using Atomic Absorption Spectrophotometry (AAS) using the AOAC official method (AOAC 2000). Potassium was analyzed using flame photometer method and phosphorus content was determined spectrophotometrically using the AOAC official method (AOAC 2000).

**Anti-nutritional factors:** Phytic acid was determined according to the method of Wheeler and Ferrel (1971). Tannin content was determined by the method described by Maxson and Rooney (1972), while oxalate was determined according to the method described by Iwuoha and Kalu (1994). Molar ratio of phytate/minerals: The mole of phytate and minerals was determined by dividing the weight of phytate and minerals with its atomic weight (phytate: 660g/mol; Ca: 40 g/mol; Fe: 56g/mol; Zn: 65g/ mol). The molar ratio between phytate and mineral was obtained after dividing the mole of phytate with the mole of minerals (Morris and Ellis1989).

**Phenolic compounds extraction and analysis:** Cactus seed flour was extracted using the method of Mau et al. (2004). Cactus pear seed flour (2.5g) was weighed, mixed with 25 ml of methanol and put in incubator shaker at 25°C overnight. The supernatant was decanted in to another conical flask and the extraction process was immediately repeated for about 2 hours. The supernatant solution was pooled and then transferred in to pre-weighed rotary evaporator flask and evaporated using a rotary evaporator at 300rpm and 40°C. The extract was oven-dried at 70°C and weighed. Total phenolic was determined calorimetrically, according to the method described by Singleton and Rossi (1965). In brief:

one ml of cactus pear seed extracts or Gallic acid standard solutions was mixed with 1ml of Folin-Ciocalteu reagent in each test tube, and incubated for 3 min at room temperature. After 3 minutes, 1ml of saturated Na<sub>2</sub>CO<sub>3</sub> solution was added and adjusted the solution to 10 ml with distilled water and incubated at room temperature in the dark place for 90 minutes. The absorbance was then read at 725nm using a UV-VIS spectrophotometer. The concentration of total phenolics was determined using the standard calibration curve of gallic acid at a linearity range of 20-160µg/ml of the curve and values were expressed as milligrams of gallic acid equivalents (mg of GAE/g of dried extract). The percentage yield extract was calculated as follows:

$$\text{Yield (\%)} = \frac{W_1}{W_2} \times 100(1)$$

Where,  $W_1$  = Weight of extract after solvent evaporation,  $W_2$  = Weight of the cactus seed flour

**Extraction and analysis of Flavonoids:** Sample extraction was done by Saura-Calixto *et al.* method (2007). Briefly: 0.4g of dried sample was mixed with 12 ml of acidified methanol water solution (50:50 v/v.pH 2) and extracted for 3 hours. The mixture was centrifuged at 2500g for 10 minutes and the supernatant was transferred to another test tube. To the residue 12 ml of acetone water (70:30 v/v) was added and extracted for another 3 hours, centrifuged and the supernatant was mixed with the first extract and stored at 40C until analysis. Total flavonoids content was determined using a colorimetric method described by Heimler *et al.* (2005). Briefly: the seed extract (0.25ml) or (+) catechin standard solution was mixed with 1.25 ml of distilled water in a test tube, followed by addition of 75µL of 5% NaNO<sub>2</sub> solution. After 6 min, 150µL of 10% AlCl<sub>3</sub>.6H<sub>2</sub>O solution was added and allowed to stand for another 5 min before adding 0.5 ml of 1 M NaOH. The mixture was brought to 2.5 ml with distilled water and vortexed. The absorbance was measured at 510 nm using a UV-Visible Spectrophotometer. The total phenolic content was determined using the standard calibration curve of (+)-catechin at a linearity range of 100-1000µg/ml of the curve and values were expressed as milligrams of (+)-catechin equivalents (mg of CAE/g of dried extract). The percentage yield extract was calculated as:

$$\text{Yield (\%)} = W_1/W_2 \times 100 \quad (1)$$

Where,  $W_1$  = Weight of extract after solvent evaporation,  $W_2$  = Weight of the cactus seed flour

**Anti-oxidant activity:** The methanolic extract was used in this regard. The radical scavenging activity of the seed extract was determined using Kirby and Schemid method (1997). Four ml 0.004% solution of DPPH methanol was mixed with 1 ml of various

concentrations (20-240 µl/ml) of sample extract in methanol and was mixed using vortex mixer. The test tube containing the solution was incubated in the dark for 30 minute at room temperature. Scavenging capacity was finally read spectrophotometrically by monitoring the decrease in absorbance at 517nm using ascorbic acid as standard. The radical scavenging activity was calculated using the formula:

$$\% \text{ scavenging activity} = \frac{A_c - A_s}{A_c} \times 100 \quad (2)$$

Where,  $A_c$  is the absorbance of the control and  $A_s$  is the absorbance of the sample.

The extract concentration providing 50% of radicals scavenging activity (IC<sub>50</sub>) was calculated from the graph of DPPH inhibition percentage.

**Functional properties:** Bulk density was determined according to the method of Narayana and Narasinga-Rao (1984). Water absorption capacity (WAC) and Water solubility index (WSI) were determined according to the method of Sosulski (1987) and Oil absorption capacity (OAC) was determined according to the method of Adeleke et al. (2010). Foaming capacity (FC) and Foam stability were determined by Mittal and Kumar procedure (2000). Product

formulation and sensory evaluation: The traditional bread Ambasha was prepared by mixing, fermenting and baking of doughs formulated with wheat flour to cactus pear seed flour ratio of 100:0; 95:5; 90:10; 85:15:80:20; 75:25. The bread was then evaluated for its sensory attributes by ten semi-trained students of the Center for Food Science and Nutrition, AAU using the seven point hedonic scale (Moskowitz and Krieger1995). Data were analyzed in triplicate using SPSS Version16. ANOVA was used to determine the difference between the means at 5% level of significance.

## Results

**Proximate composition analysis:** To the best of our knowledge, there were no published studies on the nutritional composition and other properties of cactus pear seed grown in Ethiopia although it was intensively studied in other parts of the world. Table 1 shows the proximate composition of cactus pear seed grown in Tigray, Ethiopia. Cactus pear seed predominantly contains highest amount of carbohydrate followed by fiber. The seed contains high amounts crude fiber fat.

**Table1: Proximate composition and caloric value of cactus pear seed flour (g/100g) (db).**

| Parameters    | Contents     |
|---------------|--------------|
| Moisture      | 4.17± 0.00   |
| Crude protein | 10.00± 0.17  |
| Crude fat     | 10.50 ± 0.50 |
| Crude fiber   | 18.23 ± 0.00 |
| Total Ash     | 1.63 ± 00    |
| Carbohydrate  | 55.47 ±0.44  |
| Total energy  | 392.84± 2.15 |

Values are represented as mean ±SD. of triplicate analysis.

**Minerals analysis and anti-nutritional factors:** Values for mineral contents of cactus pear seeds are given in Table 2. In the present study potassium content was very high (446.46mg/100g) followed by calcium and phosphorus whereas Zinc content was relatively low (2.01 mg/100g). Anti-nutritional factors are generally toxic and may negatively affect

the nutritional value of cactus pear seeds by impairing protein digestibility and mineral availability. The anti-nutritional factors namely phytate, tannin and oxalate were given in Table 3. The results showed that phytate content was considerably higher (259 mg/100g) than tannin (0.13mg/100g) and oxalates (0.11mg/100g).

**Table. 2: Mineral contents of cactus pear seed (mg/100g, db)**

| Components | Values       |
|------------|--------------|
| Ca         | 390.14± 0.01 |
| K          | 446.46± 0.01 |
| P          | 206.18± 0.03 |
| Fe         | 4.37± 0.00   |
| Zn         | 2.01± 0.01   |

Values are represented as mean ±SD (n=3).

**Table 3: Antinutritional factors and molar ratios of cactus pear seed (mg/100g, db)**

| Components          | Values                |
|---------------------|-----------------------|
| Phytate             | 259.20±3.700 mg/100g, |
| Tannin              | 0.13 ± 0.004 mg/100g, |
| Oxalate             | 0.11± 0.09 mg/100g,   |
| <b>Molar ratios</b> | <b>Contents</b>       |
| Phytate/Ca          | 0.04 ± 0.00           |
| Phytate/Fe          | 4.99 ± 0.05           |
| Phytate/Zn          | 12.78 ± 0.43          |

Values are represented as mean ±SD (n=3).

**Molar ratio of phytate to minerals:** The molar ratio between phytate and minerals indicates the impact on the bioavailability of dietary minerals. Accordingly, the values pointed out in Table 3 revealed that the molar ratio of both phytate: Ca (0.04) and phytate: Fe (4.99) was found to be below the critical limit. However, the molar ratio of phytate to Zn exhibited a high ratio (12.78) which was beyond the stated

critical limit. Total phenolics and flavonoids: In this study, the anti-oxidant compounds particularly total phenolics and total flavonoids (Table 4) account 90.2 mg/100g and 0.19mg/100g, respectively. The result indicated that the seeds of cactus pear contained the highest concentration of phenolic compared to flavonoids.

**Table 4: Yield of extracts, total phenolics and flavonoids content of cactus pear seed flour**

| Anti-oxidant compounds          | Means $\pm$ SD  | Yield (g/100g) |
|---------------------------------|-----------------|----------------|
| TPC (mg of GAE/100g of extract) | 90.2 $\pm$ 5.37 | 7.4            |
| TFC (mg of CAE/100g of extract) | 0.19 $\pm$ 0.02 | 5.8            |

Values are represented as means  $\pm$  SD., n=3

**Anti-oxidant activities:** It has been recognized that total phenols contents (TPC) of plant extracts are directly related with the antioxidant activities due to their high redox potentials. In the present study, the antioxidant activity of cactus pear seed was analyzed (Figure 1). Hence, the minimum and maximum capacity of cactus pear seed for scavenging free radicals in this study ranged between 43%-95%. It was also noticed from the same figure that the

percentage inhibition activity was greater than the ascorbic acid standard (20%-94.86%). The extract concentration providing 50% of radical scavenging activity ( $IC_{50}$ ) was calculated from the graph of DPPH inhibition percentage against the extract concentration. Hence, the  $IC_{50}$  of the sample extract was 1.32 mg/ml and ascorbic acid was 2.4mg/ml. The lower the  $IC_{50}$  value, the higher is the scavenging potential.

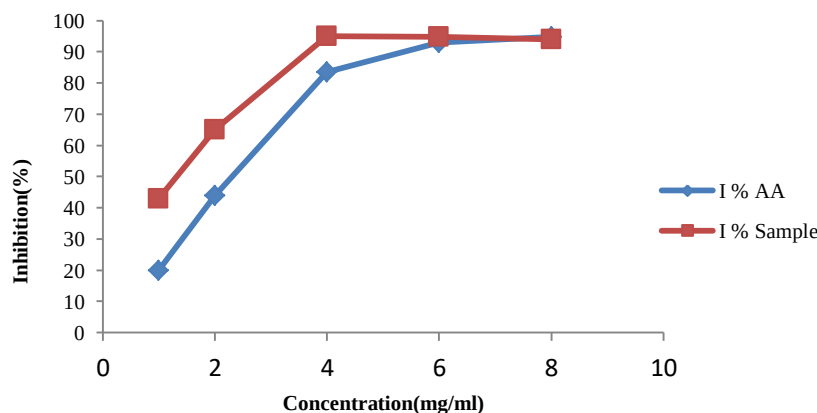


**Figure 1: Antioxidant activity of cactus pear seed and standard ascorbic acid (AA)**

**Functional properties:** Functional properties play an important role in determining the competitiveness of ingredients or products in the market, as they can impact the sensory, physical and chemical properties of a food. Some representative attributes such as bulk density, water/oil absorption capacity, foaming

capacity and foam stability, and water solubility index were analyzed to evaluate the functional properties of cactus pear seed flour (Table 5). The flour of cactus in this study is characterized by low bulk density and high water solubility index and foaming capacity.

**Table 5: Functional properties of cactus pear seed flour**

| Properties                    | Values            |
|-------------------------------|-------------------|
| Bulk density(g/ml)            | 0.80 $\pm$ 0.00   |
| Water absorption capacity (%) | 1.64.00 $\pm$ 0.1 |
| Oil absorption capacity (ml)  | 1.45 $\pm$ 0.07   |
| Water solubility index (%)    | 5.6 $\pm$ 0.00    |
| Foaming capacity (ml)         | 4.75 $\pm$ 0.35   |
| Foaming stability(ml)         | 3.75 $\pm$ 0.35   |

Values are presented as mean  $\pm$  SD. (n=3)

**Sensory evaluation of Ambasha:** In the present study the sensory characteristics of cactus pear seed flour supplemented wheat flour *Ambasha*, for its color,

taste, aroma, texture and over all acceptability. Thus, the results from Table 6 showed that there was no significant difference ( $p < 0.05$ ) between the

control(100% wheat flour) and 5% cactus pear flour supplemented *Ambasha* in all sensory attributes except texture. Based on the sensory scores marked

by the panelists, incorporation of cactus pear seed up to 15% appeared to be highly acceptable.

**Table 6: Sensory attributes of cactus pear seed and wheat flour *Ambasha***

| Wheat flour: seed flour ratio | Sensory attributes*   |                        |                         |                        |                       |
|-------------------------------|-----------------------|------------------------|-------------------------|------------------------|-----------------------|
|                               | Color                 | Taste                  | Aroma                   | Texture                | Overall Acceptance    |
| 100:0% (control)              | 8.6±0.97 <sup>a</sup> | 8.1±1.45 <sup>a</sup>  | 8.1±0.88 <sup>a</sup>   | 8.3±1.25 <sup>a</sup>  | 8.3±0.94 <sup>a</sup> |
| 95:5%                         | 7.7±2.4 <sup>ab</sup> | 7.3±2.01 <sup>ab</sup> | 8.1±0.88 <sup>a</sup>   | 6.6±2.59 <sup>b</sup>  | 7.1±2.37 <sup>a</sup> |
| 90:10%                        | 7.1±1.52 <sup>b</sup> | 7.5±1.96 <sup>ab</sup> | 7.9±0.74 <sup>ab</sup>  | 6.7±1.40 <sup>b</sup>  | 7.3±2.00 <sup>a</sup> |
| 85:15%                        | 5.8±2.42 <sup>c</sup> | 6.5±2.17 <sup>ab</sup> | 7±1.33 <sup>bc</sup>    | 6±2.7 <sup>c</sup>     | 5.5±2.79 <sup>b</sup> |
| 80:20%                        | 4.4±2.22 <sup>d</sup> | 5.8±1.93 <sup>bc</sup> | 7.1±1.44 <sup>abc</sup> | 5.3±2.45 <sup>cd</sup> | 4.9±1.05 <sup>b</sup> |
| 75:25%                        | 3.6±2.22 <sup>d</sup> | 4.6±1.78 <sup>c</sup>  | 6.7±1.42 <sup>c</sup>   | 4.4±2.22 <sup>d</sup>  | 4.3±2.49 <sup>b</sup> |

Values are represented as mean±SD. Means followed by the same superscript letter in the same column are not significantly different ( $p < 0.05$ )

## Discussion

Several studies have reported that cactus pear seeds can be used as a source of food due to sit has high content of protein, fiber, lipids, minerals and carbohydrates (1993). Of these nutritional components, the present study indicated that cactus pear seed predominantly contains highest amount of carbohydrate followed by fiber in agreement with the study of Nassar (2008). Dietary fiber is known to prevent a variety of diseases. Soluble fiber produces viscous solutions that lower the absorption and the clearing of the small intestine, delays the increment of glucose and cholesterol in the blood and induces the intestinal transit time (Dulce et al. 2014). The cactus pear seed fat content is relatively higher compared to most cereals (Piga 2004). With regard to mineral contents, cactus pear seed has significant amounts of potassium calcium and phosphorus with low zinc content similar to the findings of El-Safy et al. (2012) and El-Kossori et al. (1998). Anti-nutritional factors: Ant-nutritional factors are generally toxic and may negatively affect the nutritional value of cactus pear seeds by impairing protein digestibility and mineral availability. The anti-nutritional factors reported in this study are phytates, tannin and oxalate. The presence of appreciable amounts of condensed tannins in cactus pear seeds are importance in the health promotion because of their antioxidant activities (Özcan and Al Juhaimi 2011). However, these antinutritional factors can be minimized or eliminated using some processing methods such as soaking, cooking and fermentation (El-Safy et al 2011).

The critical molar ratio, above which mineral absorption may be inhibited, has been determined as PA: Ca>1.56, PA: Fe >14 and PA: Zn >10 (Saha et al. 1994). In this study these limits were employed to predict the bioavailability of minerals. As indicated in Table 2, the bioavailability of calcium and iron is not inhibited by the concentration of phytate present in the cactus pear seed flour. In contrast, the bioavailability of Zn in the seeds is inhibited by phytate. Therefore, the risk of Zn inhibition in this

regard requires a preferable mode for minimization of the concentration of phytate in the cactus pear seeds. Phenolic compounds are reactive metabolites in a wide range of plant-derived foods. They function as terminators of free radicals and chelators of metal ions that are capable of catalyzing lipid oxidation. The results of this study showed that total phenolic content was comparable with the findings (48-89 mg/100g) of El-Mostafa et al (2014). However, results of phenolics and flavonoids are in contrast to the findings of Chougui et al. (2013) which reported 268 mg/100g and 74 mg GAE/100g, respectively. Such differences could be attributed to variations in plant species and climatic conditions under which the plants have grown (Naczek and Shahidi 2006). The concentration of the cactus seed flour extract required for the formation of IC<sub>50</sub> was similar to the ascorbic acid standards but lower than the results recorded by Toure et al. (2015). Bulk density influences the amount and strength of packaging materials, energy density, texture, and mouth feel (Udensi 2006). All investigated functional properties except bulk density were lower than the results reported by El Safy et al. (2012). However, the functional attributes of products may vary considerably due to the differences in the raw material, processing methods and environmental conditions used during testing.

**Sensory evaluation of *Ambasha*:** In the present study, the sensory characteristics of wheat flour-cactus pear seed flour supplemented *Ambasha*, for its color, taste, aroma, texture and over all acceptability. Thus, the results from Table 6 showed that there was no significant difference ( $p < 0.05$ ) between the control (100% wheat flour) and 5% cactus pear flour supplemented *Ambasha* in all sensory attributes except texture. Based on the sensory scores marked by the panelists, incorporation of cactus pear seed up to 15% appeared to be acceptable. *Ambasha* prepared with 85% wheat flour and 15% seed flour combination was most preferred by the panelists. The level of acceptance of the *Ambasha* decreased with increasing concentration of cactus pear seed flour in agreement with the study of Saenz (2000).

## Conclusions

Cactus pear seed flours can be consumed by formulating with wheat flours up to a limited ratio as indicated in this study. The seed flours may also be used to supplement other cereal such as teff, sorghum and barley although further studies may be required.

## Acknowledgments

The authors gratefully acknowledge the Center for Food Science and Nutrition, College of Natural and Computational Sciences, Addis Ababa University, for supporting this study.

## References

- Adeleke RO & Odedeji JO (2010). Functional properties of wheat and sweet potato flour blends. *Pakistan Journal of Nutrition*, 9(6): 535-538.
- Association of Official Analytical Chemists (AOAC). (2000). *Official Method of Analysis*, 17<sup>th</sup> Edition, Gaithersburg. Pp. 2200.
- Chougui N, Tamendjari A, Hamidj W, Hallal S, Barras A, Richard T et al. (2013). Oil composition and characterization of phenolic compounds of *Opuntia ficus-indica* seeds. *Food Chemistry*, 139(1): 796-803.
- Dulce M, Jiménez A, Hugo MP & Jorge WC (2014). Photochemical characterization of prickly pear (*Opuntia* spp.) and of its nutritional and functional properties: A Review. *Current Nutrition and Food Science*, 10: 57-69.
- El Kossori RL, Villaume C, El Boustani E, Sauvaire Y & Méjean L (1998). Composition of pulp, skin and seeds of prickly pears fruit (*Opuntia ficus indica*). *Plant Foods for Human Nutrition*, 52(3): 263-270.
- El-Mostafa K, El Kharrassi Y, Badreddine A, Andreoletti P, Vamecq J, El Kebbj M et al. (2014). Nopal Cactus (*Opuntia ficus-indica*) as a source of bioactive compounds for nutrition, health and disease. *Molecules*, 19: 14879-14901.
- El-Safy FS, Salem RH & Abd El-Ghany ME (2012). Chemical and nutritional evaluation of different seed flours as novel sources of protein. *World Journal of Dairy and Food Sciences*, 7(1): 59-65.
- Felker P & Guevara JC (2001). An economic analysis of dry land fruit production of *Opuntia ficus indica* in Santiago del Estero. *Journal of Professional Association for Cactus Development*, 4: 20-30.
- Heimler D, Vignolini P, Dini MG & Romani A (2005). Rapid tests to assess the antioxidant activity of *Phaseolus vulgaris* L. dry beans. *Journal of Agricultural and Food Chemistry*, 53(8): 3053-3056.
- Iwuoha CI & Kalu FA (1994). Calcium oxalate and physicochemical properties of cocoyam (*Colocasia esculents* and *Xanthosoma saquilfolnim* tuber flours as affected by processing. *Food Chemistry*, 54: 61-66.
- Joubert E (1993). Processing of the fruit of five prickly pear cultivars grown in South Africa. *International Journal of Food Science and Technology*, 28: 377-387.
- Kirby AJ & Schmidt RJ (1997). The antioxidant activity of Chinese herbs for eczema and of placebo herbs. *Journal of Ethnopharmacology*, 56(2): 103-108.
- Moskowitz R. & Krieger B (1995). The contribution of sensory liking to overall liking: an analysis of six food categories. *Food Quality and Preference*, 6: 83-90.
- Mau JL, Chang CN, Huang SJ & Chen CC (2004). Antioxidant properties of methanolic extracts from *Grifola frondosa*, *Morchella esculenta* and *Termitomyces albuminosus* mycelia. *Food Chemistry*, 87(1): 111-118.
- Maxson ED & Rooney LW (1972). Evaluation of methods for tannin analysis in sorghum grain. *Cereal Chemistry*, 49(6): 719-721.
- Mittal KL & Kumar P (2000). Emulsion, foams and thin films. Marcel Dekker, Inc., New York, USA.
- Morris ER & Ellis R (1989). Usefulness of the dietary phytic acid/zinc molar ratio as an index of zinc bioavailability to rats and humans. *Biological Trace Elements Research*, 19: 107- 117.
- Mondragón-Jacobo C, Pérez-González S (2001). Cactus (*Opuntia* spp.) as forage. *Food and Agriculture of the United Nations*, 92(5): 169.
- Nacz M & Shahidi F (2006). Phenolics in cereals, fruits and vegetables: Occurrence, extraction and analysis. *Journal of Pharmaceutical and Biomedical Analysis*, 41(5): 1523-1542.
- Narayana K & Rao MN (1984). Effect of partial proteolysis on the functional properties of winged bean (*Psophocarpus tetragonolobus*) flour. *Journal of Food Science*, 49(3): 944- 947.
- Nassar AG (2008). Chemical composition and functional properties of prickly pear (*Opuntia ficus indica*) seeds flour and protein concentrate. *World Journal of Dairy and Food Sciences*, 3(1): 11-16.
- Nobel PS (1988). Environmental Biology of agaves and cacti Cambridge University press.
- Özcan M & Al Juhaime Y (2011). Nutritive value and chemical composition of prickly pear seeds (*Opuntia ficus indica* L.) growing in Turkey. *International Journal of Food Sciences and Nutrition*, 62(5): 533-536.
- Piga A (2004). Cactus pear: a fruit of nutraceutical and functional importance. *Journal of the Professional Association for Cactus Development*, 6: 9-22.

- Russell CE & Felker P (1987). The prickly-pears (*Opuntia* spp., Cactaceae): a source of human and animal food in semiarid regions. *Economic Botany*, 41(3): 433-445
- Saha PR, Weaver CM & Mason AC (1994). Mineral bioavailability in rats from intrinsically labeled whole wheat flour of various phytate levels. *Journal of Agricultural and Food Chemistry*, 42(11): 2531-2535.
- Saenz C (2000). Processing technologies: an alternative for cactus pear (*Opuntia* spp.) fruits and cladodes. *Journal of Arid Environments*, 46(3): 209-225.
- Saura-Calixto F, Serrano J & Goñi I (2007). Intake and bioaccessibility of total polyphenols in a whole diet. *Food Chemistry*, 101(2): 492-501.
- Singh G (2003). General review of opuntias in India. *Journal of Professional Association of Cactus Development*, 5: 30-46.
- Singleton VL & Rossi JA (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American journal of Enology and Viticulture*, 16(3): 144-158.
- Sosulski FW, & McCurdy AR (1987). Functionality of flours, protein fractions and isolates from field peas and faba bean. *Journal of Food Science*, 52(4): 1010-1014.
- Toure H, Bouatia M, Idrissi M & Draoui M (2015). Phytochemical screening and antioxidant activity of aqueous-ethanolic extracts of *Opuntia ficus indica*. *Journal of Chemical and Pharmaceutical Research*, 7(7): 409-415.
- Udensi EA (2006). Effects of fermentation and germination on the physicochemical properties of *Mucuna cochinchinensis* protein isolate. *African Journal of Biotechnology*, 5(10): 896 (APA).
- Wheeler EL & Ferrel RE (1971). Method for phytic acid determination in wheat and wheat fractions. Western Regional Research Laboratory, Agricultural Research Service and US Department of Agriculture. *African Journal of Food Science*, 3(1): 22-25.