Enhanced Bio-functional activity of cupcake by addition juice and powder of organic prickly pear (*Opuntia ficus indica*) fruit skin

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Abstract:

Recently, attention has increased to production functional foods by use natural sources rich with bioactive compounds to enhance the functional characteristics of food products. Prickly pear (*Opuntia ficus indica L.)* is a rich source of the phyto-chemicals. Therefore, the current study was targeted to first determine the approximate chemical composition and physical characteristics of prickly pear skin powder (PPSP), prickly pear skin juice (PPSJ) and wheat flour (WF 72%). In addition, total phenolic compounds (TPC) total flavonoids (TF), and total antioxidant capacity (TAC) were determined. Then, produce and evaluated the organoleptic proprieties of an innovative cupcake with (50 and 100%) of PPSJ and (10 and 20 %) of PPSP.

Results indicated that PPSP had the highest fiber and ash followed by PPSJ then WF. Addition PPSJ at (50 and 100%) to cupcake formula influence on moisture drastically, and substitute WF with PPSP at (10 and 20%) had decrease in protein and carbohydrates content, but led to increase the fiber and ash content compare to WF cupcake. The PPSP and PPSJ cupcake at different levels were recorded higher TPC, TAC and DPPH than WF cupcake. Also, data indicated that increasing both PPSP and PPSJ levels increased the phytochemical compounds especially for PPSJ 100% cupcakes recorded the highest TPC, TAC and DPPH contents to be 102.90 mg GAE/100g, 109.35 and 51.83 respectively. Afterwards, cupcake by PPSP 20% recorded highest TPC, TAC and DPPH contents to be 95.23 mg GAE/100g, 95.45 and 51.70 respectively. Organoleptic evaluation results show an addition level up to 10% PPSP and 50% PPSJ in cupcakes was well accepted and doesn't effect on their overall quality. So, that could be used in the production of functional, healthy cupcake and therefore such a product can be marketed.

Keywords: Cactaceae family; by-product; bioactive compounds; nutrition value

1. Introduction:

Fruits are food items rich in phytochemicals that are widely consumers due to the health benefits they offer against obesity, diabetes type2, hypertension, cardiovascular diseases and cancer **(Velasco *et al.*, 2022).** Prickly pear (*Opuntia ficus indica L.*) is one of the most fruits prevalence in Egyptian culture is belongs to the Cactaceae family. It grows in Europe, Africa, Middle East and India in particular environmental conditions such as low precipitation with high or low temperatures **(Doğan *et al.*, 2016; Márquez-Montes *et al.*, 2023).** Also, called cactus fruit, cactus figs or Indian figs; it is a small tree and the fruit is an elongated oval-shaped berry with a thick pericarp (semi-hard) rind with thorns that peel accounts for 33–55% of the fruit and with juicy pulp, that pulp makes up about 45–67% and seeds are good sources of unsaturated edible oils and accounts for 2–10% of the pulp **(Sheha and El Gezery, 2018; Abdelfattah *et al.*, 2020; De Wit *et al* ., 2020).** Pulp may have different colors such as green, greenish white, canary yellow, lemon yellow, red, cherry-red, or purple hues **(Puri, 2024).**

Prickly pear represents a digestible energy-balanced food, moderately high in sugars, starch, and the mixture of yellow betaxanthin and red betacyanin pigments **(Todaro *et al.*, 2020).** And it consider rich source of dietary fibers and phytochemicals such as betalains and β-carotene, lipid-soluble antioxidants and various flavonoid compounds (e.g., kaempferol, quercetin) **(Akelom *et al.*, 2022).** As well as, cactus fruit is rich in calcium, potassium, magnesium, selenium and significant content of lipid and phytosterols **(Gouws, 2020).** Seeds, peel and juicy pulp are rich in acids as (stearic, oleic, ferulic, palmitic and vaccenic) **(Badawi *et al.*, 2021).**

The prickly pear fruit is mainly eaten as a fresh fruit after the peel has been removed. This results in a large availability of this agro-industrial by-product, a source of digestible dietary fibre and rich in bioactive compounds **(Gannuscio *et al.*, 2024).** Also, prickly pear peels (PPPs) are source of protein, carbohydrates, minerals, β-carotene, cellulose and amino acid (**Badr *et al.*, 2017).**

PPPs have twice the dietary fiber content of the fruit pulp, with a high percent of insoluble fiber and antioxidant compounds like polyphenols, flavonoids which provides beneficial effects for human health becoming bioactive in the human intestine, such as lipid-lowering and hypoglycemic**(Manzur-Valdespino *et al.*, 2020).** The prickly pear byproducts possess antioxidant, antimicrobial, anti-inflammatory, help promote health and prevent certain diseases, neuro-protective or hypoglycemic characteristics **(Badawi *et al.*, 2021; Sabtain *et al.*, 2021; Yazhini and Krishna, 2023)** inhibition of stomach ulceration and indigestion **(Abd El-Razek and Hassan, 2011).**

Prickly pear juice has desirable technological characteristics such as high content of vitamin C (**Hijazi, 2017),** and it is a source of betaxanthin pigments which can be used as water-soluble natural colorants in foods, rich in phenolic compounds, and a strong source of minerals (magnesium, phosphorus and calcium); which it help to prevent cramps, osteoporosis and chronic disease **(Hamad *et al.*, 2024).**

Global trends in food and nutrition indicate a growing interest in the consumption of fruits because the nutritional value for the compounds in the fruits which improve health and prevention of human diseases **(El-Neney *et al.*, 2019; Temagoult *et al.*, 2023).**These trends have led to a new area of research and development in nutrition so-called "functional foods", defined as any food, either natural or processed, which in addition to its nutritional components contains substances that boost a person's health, physical ability and mental state **(Ramírez *et al.*, 2018).**

In the recent years as bakery products have diversified significantly by adding various ingredients characterized with high nutritional value among these ingredients (dietary fibers and phytochemicals). By-products from processing of fruits include high number of natural compounds or food additives possibility of transformation fruit by-products in flour; which improvement in the nutritional and functional properties by combining flour with powdered **(El-Shahat *et al.*, 2017; Mahfouz and Abd-Elnoor, 2020; Parafati *et al.*, 2020)**. So, the current study aimed to elaborate cupcake enriched with prickly pear

fruit skin (powder or juice) with different level, determination the chemical composition and bio-active compounds; as well as, evaluate the sensory properties of these products.

2. Materials and methods:

2.1. Materials:

Prickly pear skins were collected from El-Minia market during July 2024 and the main ingredients which used in this study (wheat flour 72%, eggs, sugar, corn oil, vanilla, baking powder and yogurt) were obtained from a local market in Minia City, Minia Governorate, Egypt.

-Reagents and chemicals

Chemicals and solvents were obtained from El-Gomhoryia Company for chemicals, medical instruments and trading drugs, Cairo, Egypt.

2.2. Methods:

-Preparation prickly pear skin (powder and juice)

Prickly pear skins washed and using hot air oven drier at 50 ± 5◦C for 24 hours for dried them; after drying the thorns were removed and then were milled by using a laboratory grinder to obtain prickly pear skin powder (PPSP). Powder was kept in the refrigerator.

As for juice, it is prepared according to **Ayadi *et al.*, (2009)** method as follows: Prickly pear skin were washed and homogenized with a warring blender (Philips, France) to obtain juice. The prickly pear skin juice (PPSJ) was filtered through a cloth, and this process was repeated twice to remove the thorns. Juice was kept in glass jars at 4°C until they were analysed and products prepared**.** Prickly pear skin powder and juice were used as raw materials todetermine the chemical and physical characteristics and products prepared.

-Preparation of cupcake

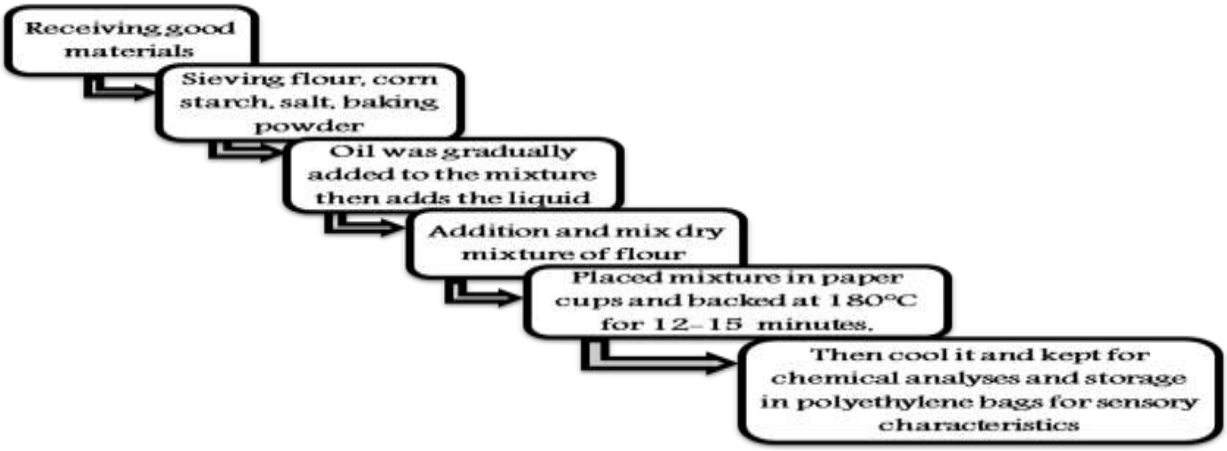
According to **Rebecca *et al.*, (2016)** and **Pathan *et al.*, (2019)**, cupcake was prepared with some modifications in the method will clarified in Table (1).

Table (1): Formula of Cupcake

Ingredients	Control (WF100%)	PPSP 10%	PPSP 20%	PPSJ 50%	PPSJ 100%
WF	130g	117 g	104 g	130g	130g
PPSP	—	13 g	26 g	—	—
Water	50 ml	50 ml	50 ml	25 ml	—
PPSJ	—	—	—	25 ml	50 ml
Corn Starch	20 g	20 g	20 g	20 g	20 g
Corn oil	45 ml	45 ml	45 ml	45 ml	45 ml
Salt	0.5 g	0.5 g	0.5 g	0.5 g	0.5 g
Sugar	100g	100g	100g	100g	100g
Baking powder	8 g	8 g	8 g	8 g	8 g
Egg	1	1	1	1	1
Vanilla essence	4 g	4 g	4 g	4 g	4 g

WF 100%: Wheat flour 100%
PPSP 10%: 90% Wheat flour + 10% prickly pear skin powder
PPSP 20%: 80% Wheat flour + 20% prickly pear skin powder
PPSJ 50%: 100% Wheat flour + 25 ml prickly pear skin juice
PPSJ 100%:100% Wheat flour + 50 ml prickly pear skin juice

- Method of Preparation



-Determination of chemical composition of PPSP, PPSJ and cupcake:

At the Agriculture Research Center, we assessed moisture, protein, ash, fat, and crude fiber using the methods described in **A.O.A.C. (2012).**

-Determination of phytochemical compounds:

According to **Bakar *et al.*,(2009); Oms-Oliu *et al.*, (2009); Musa *et al.*, (2011); Kanika *et al.*,(2015)** determined of total flavonoids, 2, 2- diphenyl -1 picrylhydrazyl (DPPH) radical scavenging ability, total phenols and total antioxidant capacity respectively.

-Determination of weight, volume and specific volume of cupcake samples:

According to **Randez-Gil *et al.* (1995)**, the weight and volume were determined after preparing cupcakes with PPSP and PPSJ; subsequently, the specific volume of the cupcake samples was determined after one hour of baking. To ascertain the specific volume, the weight-to-volume ratio was calculated.

-Determination of color:

The color characteristics of the samples were measured by a color difference meter (model color Tec-PCM, USA) using different color parameters (L, a, b) according to **Francis, (1983).** In addition, numerical total color difference (ΔE), hue angle and color intensity (Chroma) were calculated according to **Shih *et al.*, (2009)** using the following equations: $\Delta E = [(L - Lo)^2 + (a - ao)^2 + (b - bo)^2]^{1/2}$ Hue angle = $[\tan^{-1}) b/a)]$ Chroma = $[(a^2 + b^2)]^{1/2}$ Where: Lo , ao and bo were the L, a, and b values of the reference sample which is here the fresh sample.

-Evaluation organoleptic properties of cupcake

20 panelists, postgraduates, comprising faculty and students from the Agriculture and Specific Education at Minia University in Egypt, participated in the sensory evaluation. Each participant received 5 randomly coded samples of each product on a round glass plate. The products (cupcake) were created with composite wheat flour, prickly pear skin powder and its juice. 10-point scales were used to evaluate the taste, texture, odor, color and overall acceptability of samples. To rinse the samples in between, water was provided.

-Ethical Approval

Experiments, especially the sensory evaluations for this study were approved by ethical standards approved by Scientific Research Ethics Committee (SREC) Faculty of Specific Education, Minia University, Egypt.

- Statistical Analysis

Using the General Linear Model software as statistical analysis method were analyzed data **(SAS, 2003)** and use double range tests to compare average **(Duncan, 1955)**.

3. Result and discussion

3.1. Analysis of Nutritional Composition

3.1.1. Moisture, Fiber, Ash, Protein, Fat and Carbohydrates Contents

The proximate analyses of WF, PPSP and PPSJ were presented in Table (2). The results clarified that the moisture content of WF, PPSP and PPSJ was (10.37, 5.86 and 85.32 %) respectively, protein content varied from (10.74, 4.66 and 0.47%) for WF, PPSP and PPSJ respectively.

In the same Table data were observed that PPSJ were recorded the highest content of moisture 85.32%; while PPSP had the highest value of fiber and ash was recorded 21.02 and 10.79% respectively. On other hand, results were showed that PPSP had the highest value of fat content was 4.51% followed by WF was 2.20% more than PPSJ was 0.50%. WF was recorded the lowest content of fiber and ash was (0.75 and 0.54%) respectively. Also, WF recorded high rate of carbohydrates content was 75.38% compared to PPSP and PPSJ were (53.29 and 9.22%) respectively. The chemical composition of prickly pear indicates provides both a high nutritional value and various health benefits **(Abbas *et al*., 2022)**.

Our results were in agreement with **Parafati *et al.*, (2020)** reported that prickly pear peel flour evidenced a low moisture percentage and exhibited a good protein and fat content and evidenced an elevated amount of total dietary fiber. And with results obtained by **Djeghim *et al.*, (2021)** explained that dried prickly pear peel contain 52.53 % carbohydrates; while our results were disagreement with results obtain

by the same authors in moisture, protein, fat, fiber, ash content were (10.29, 8.48, 1.69, 7.41 and 19.60%) respectively.

Also, **Manzur-Valdespino *et al.*, (2022)** showed that cactus pear peel (CPP) is notorious carbohydrates are major component, its high percentage of moisture, low amount of fats and proteins and are rich in fibers. **Ramírez *et al.*, (2018)** indicated that the potential of these prickly pear juices as functional foods is high due to outstanding content of soluble fiber.

In the same Table, it could be noticed that result of proximate analyses of WF in the line with the results were obtained by **Karwasra *et al.*, (2021)** revealed that wheat flour contains protein (11.7%). And with **Sharawy *et al.*, (2023)** explained that WF content of protein, moisture and carbohydrate WF was (10.75, 10.65 and 76.33 %) respectively.

Table (2): Proximate analysis of WF, PPSP and PPSJ

Chemical Composition ($g.100g^{-1}$)	WF	PPSP	PPSJ
Moisture	10.37^{b}±0.075	5.86^{c}±0. 17	85.32^{a}±0.14
Protein	10.74^{a}±0.11	4.66^{b}±0.07	0.47^{c}±0.03
Fat	2.20^{b}±0.15	4.51^{a}±0.09	0.50^{c}±0.05
Fiber	0.75^{c}±0.07	21.02^{a}±0.08	3.32^{b}±0.09
Ash	0.54^{c}±0.03	10.79^{a}±0.10	1.32^{b}±0.02
Carbohydrates	75.38^{a}±0.32	53.29^{b}±0.36	9.22^{c}±0.14
Dry matter (%)	89.635	94.27	14.83

* Each value reflects the mean value of three ± SD replicates.

* Mean values of various letters in the same raw average at p≤0.05 stage is substantially different.

3.2. Phytochemicals Composition

3.2.1. Total phenols, total flavonoid and total antioxidant capacity of WF, PPSP and PPSJ

Plants are produces several of natural antioxidants compounds to counteract reactive oxygen species (ROS) **(Jiang *et al.*, 2021).** The antioxidant activity of prickly pear it exerts biological effects, is comparable to that of red oranges and grapes, which may be due to the synergistic action of betalains pigment, phenols compounds, flavonoids

and other biologically active components **(Stintzing *et al.*, 2005; Cano *et al.*, 2017).** Flavonoids and phenolic acids are the main polyphenols of *(Opuntia ficus-indica*) **(Slimen *et al.*, 2016)**.

In this study, were obtained the our finding in Table (3) present the content of total phenols (TPC), total flavonoid (TFC), total antioxidant capacity (TAC) and DPPH of WF, PPSP and PPSJ. The highest TPC and TFC was observed in PPSP (2464.6 mg GAE /100g and 1152.3 mg/100g), followed PPSJ (851.9 mg GAE /100g and 345.9 mg/100g), whereas the lowest value was observed in WF (60.27 mg GAE /100g and13.10 mg/ 100g) respectively. Our results were in agreement with **Abd El-Razek and Hassan, (2011) & Castro *et al.*, (2019)** confirmed that *Cactus* fruit juice and prickly pear peels are excellent sources of bioactive compounds, such as total phenols, dietary fiber, betalains and flavonoids.

Table (3): Total phenols, flavonoids and antioxidant activity of WF, PPSP and PPSJ

Parameters	WF	PPSP	PPSJ
TPC (mg GAE/100g)	$60.27^{c}\pm0.69$	$2464.6^{a}\pm3.35$	$851.9^{b}\pm.97$
TFC (mg quercetin /100g)	$13.10^{a}\pm1.01$	$1152.3^{b}\pm0.98$	$345.9^{c}\pm0.1$
TAC	$33.2^{c}\pm0.28$	$885.12^{a}\pm1.01$	$512.6^{b}\pm0.18$
DPPH%	$16.83^{c}\pm0.08$	$76.92^{a}\pm0.60$	$55.06^{b}\pm0.09$

* Each value reflects the mean value of three ± SD replicates.
* Mean values of various letters in the same raw average at p≤0.05 stage is substantially different.

Our result of phenolic content in prickly pear skin is very higher than that found in the fruit juice; where's **Elshehy *et al.*, (2020)** reported that TPC in prickly pear juice was 123.56 mg/100g. Also, our results were in agreement with data obtain by **Yeddes *et al.*, (2013)** confirmed that peels have higher flavonoids than pulp. **Asiri *et al.*, (2024)** found that phytochemical finding for cactus pear peel (CPPP), revealing high levels of total polyphenols (1243.82 mg GAE/100g) and total flavonoids (18.92 mg QE/100g).

The % DPPH indicates the free-radical scavenging activity of the antioxidants (**De Wit *et al.*, 2020)**. And polyphenols are known that the most abundant antioxidants being largely present in plant-based food and prickly pear fruit rich in several polyphenolic compounds with a more antioxidant effect than vitamins **(Thabtia *et al.*, 2012 and Palmeri *et al.*, 2020)**.

As a result of the high content of the above-mentioned compounds, data in the same Table (3) confirmed the effective concentrations of TPC and TFC which determined by DPPH radical-scavenging activity for PPSJ and PPSP. PP SP has higher content was (885.12 and 76.92%), followed PPSJ (512.6 and 55.06%); whereas the lowest value was observed in WF (33.2 and 16.83%) respectively. Our results were in agreement with data obtained by **Dehbi *et al.*, (2013)** reported that the DPPH for juices were significantly different according to the varieties of cactus pear juices and varied between (52.48 and 135.96).

Furthermore, **El-Hassan *et al.* (2022)** confirmed that the capacity of antioxidant compounds is essential for free radical scavenging properties, and all PPP extracts exhibited antioxidant activity, with inhibition values ranging from 8.22 to 90.97%. **Castro *et al.* (2019)** reported that the reduction of DPPH radical by the peel extracts has been attributed to the presence of phenolic compounds; the increased amount of phenolic compounds led to an increase in antioxidant effects. Consumption of PPJ may contribute to the prevention or treatment of diseases associated with an excess of free radicals **(Ramírez *et al.*, 2018)**.

3.3. Analysis Nutritional Value of Cupcake

3.3.1. Proximate analysis of cupcake fortified with various levels of PPSP and PPSJ

Enhancing the nutritional value of products that are consumed represents the main strategy to meet consumers who are looking for better nutritional options and more health benefits **(Salem *et al.*, 2024**). The nutritional quality of a product is depending on the quality and quantity of the nutrients. In the present study, Table (4) shows the chemical analyses of the standard cupcakes as enriched with prickly pear skin (powder or juice).

Data in Table (4) confirmed that significant differences were observed in nutritional value of cupcake produced with PPSP and PPSJ compared to control cupcake. The addition of PPSP at level (10 and 20%) led to increase fiber content (2.21 to 4.49%), ash content (1.62 to1.91%) and fat content (19.61 to 20.44%) respectively. And according to the results can be declared that cupcake which enhanced by PPSP (20%) and PPSJ (100%) as a high source of fiber (4.49 and 1.35%) and ash content (1.91 and 1.54%) respectively compared to WF cupcake.

Our results were consistent with the data obtained by **Arafa *et al.*, (2023)** reported a significant increase in dietary fiber and ash contents of balady bread prepared with PPP and PPS, which increased proportionally with the replacement ratio. Furthermore, these findings align with the data obtained by **Mahfouz and Abd-Elnoor, (2020)** observed that the total dietary fiber and ash content increased in cake fortified with 10% prickly pear peel flour compared to the control cake. These nutritional compounds can play a crucial and essential role in food applications. **Anwar and Sallam, (2016)** elucidated that dietary fibers enhance intestinal motility, facilitate digestion and excretion, and reduce plasma cholesterol levels.

Results in Table (4) showed significant increase was observed in moisture content in cupcake product with increase of PPSP and PPSJ ratio; the highest moisture content was observed in cupcake with PPSJ 100% was (23.74%), followed cupcake with PPSJ 50% (23.38%); whereas the lowest value was observed in cupcake produced with WF 100% (21.89%).

Our results were consistent with those obtained by **Abou-Zaid *et al.*, (2022)** reported that cookies produced with prickly pear peel juices had higher moisture content (13.80%). Additionally, our findings aligned with those of **Mahfouz and Abd-Elnoor, (2020)** indicated that the percentage of moisture in the cake prepared by replacing wheat flour with 10% PPP ranged from 32.53 to 31.58%.

Table (4): Proximate analysis of prickly pear skin cupcake

Chemical Composition ($g.100^{g-1}$)	Control WF100%	PPSP 10%	PPSP 20%	PPSJ 50%	PPSJ 100%
Moisture	$21.89^{b}\pm0.19$	$21.99^{b}\pm0.99$	$22.37^{b}\pm0.38$	$23.38^{a}\pm0.78$	$23.74^{a}\pm0.71$
Protein	$13.20^{a}\pm0.66$	$11.81^{b}\pm1.19$	$10.655^{c}\pm0.59$	$13.34^{a}\pm0.52$	$13.37^{a}\pm0.93$
Fat	$17.42^{c}\pm0.85$	$19.61^{b}\pm0.41$	$20.44^{a}\pm0.71$	$17.53^{c}\pm0.93$	$17.91^{c}\pm0.79$
Fiber	$0.753^{d}\pm0.2$	$2.211^{b}\pm0.8$	$4.49^{a}\pm1.05$	$1.033^{cd}\pm0.09$	$1.35^{c}\pm0.05$
Ash	$1.45^{d}\pm0.04$	$1.62^{b}\pm0.13$	$1.91^{a}\pm0.07$	$1.48^{d}\pm0.02$	$1.54^{c}\pm0.07$
Carbohydrates	$45.29^{a}\pm0.11$	$42.64^{b}\pm0.86$	$40.135^{c}\pm1.14$	$43.05^{b}\pm.1.46$	$42.42^{b}\pm0.85$
Dry matter (%)	$78.01^{a}\pm0.99$	$77.63^{b}\pm0.37$	$76.62^{c}\pm0.51$	$76.26^{c}\pm1.86$	$76.11^{c}\pm2.14$
Kilocalorie(Kcal)	$390.74^{a}\pm0.82$	$394.29^{a}\pm0.55$	$387.12^{b}\pm0.42$	$383.33^{c}\pm0.52$	$384.35^{c}\pm0.55$

* Each value reflects the mean value of three ± SD replicates.

* Mean values of various letters in the same raw average at $p\leq0.05$ stage is substantially different.

Conversely, our findings were in disagreement with results obtained by **Bouazizia *et al.*, (2020)** reported that the moisture content significantly decreased with the increase of prickly pear peel flour. Our results were consistent with those obtained by **Abou-Zaid *et al.*, (2022)** reported that cookies produced with prickly pear peel juices had higher moisture content (13.80%). Additionally, our findings aligned with those of **Mahfouz and Abd-Elnoor, (2020)** indicated that the percentage of moisture in the cake prepared by replacing wheat flour with 10% PPP ranged from 32.53 to 31.58%. Conversely, our findings were in disagreement with results obtained by **Bouazizia *et al.*, (2020)** reported that the moisture content significantly decreased with the increase of prickly pear peel flour.

Data in Table (4) showed significant decreased in carbohydrates content and Kcal value of cupcake produced with PPSP and PPSJ compared to control cupcake. The highest carbohydrates content was observed in cupcake produced with 100% WF was (45.29%), followed cupcake with 50% PPSJ (43.05%); whereas the lowest value was observed in cupcake with 20% PPSP (40.135%).Our result were much lower than those by **Parafati *et al.*, (2020)** reported that total content carbohydrates from prickly pear peel flour 73.41%. **Sánchez, (2016)**

explained that sugar is the energy source from prickly pear fruit absorbed by the organism and becomes readily available for brain and cell function.

3.4. Phytochemicals Composition

3.4.1. Antioxidant activity of cupcake fortification by various levels of PPSP and PPSJ

Data in Table (5) showed the findings relating to the bioactive components of cupcake samples prepared by adding PPSP and PPSJ. Significant differences were observed in the amount of TPC and TFC in the control cupcake and samples prepared by adding different levels of PPSP (10-20%) and PPSJ (50-100%). Wheres results indicated that cupcake fortification by PPSJ at level 100% exhibited increased in value of TPC, TFC and TAC (102.90 mg GAE/100g, 49.00 mg quercetin /100g and 109.35) respectively; followed by cupcake fortification by PPSP at level 20% was (95.23 mg GAE/100g, 46.15 mg quercetin /100g and 95.45) compared to cupcake prepared by 100% WF.

From these data it could be observed that cupcake fortification by 100% PPSJ showed strong activity in DPPH (51.83%) because of its high phenolic content (102.90 mg GAE/100g); followed by cupcake fortification by 20% PPSP showed DPPH activity (51.70%); while cupcake prepared by 100% WF showed relatively low DPPH activity (28.97%) because of its low content of total phenolics (65.38 mg GAE.100g). **Abou-Elella and Ali**, **(2014)** confirmed that significant relationship of the Egyptian Prickly Pear Cactus *(Opuntia ficus-Indica)* peel antioxidant potency with the total phenolic content.

The results of our investigation corroborate the findings of multiple studies in the field. Research conducted by **El-Beltagi *et al.*, (2023)** revealed that the addition of prickly pear peel flour (PPPF) at levels of 5%, 10%, and 15% significantly enhanced the total phenolic content (TPC) and total flavonoid content (TFC) in cake formulations. Their study also demonstrated an increase in antioxidant activity (DPPH) across various PPPF concentrations compared to the control cake.

Table (5): Total phenols, total flavonoids, total antioxidant capacity and DPPH of prickly pear skin cupcake

Parameters	Control WF100%	PPSP 10%	PPSP 20%	PPSJ 50%	PPSJ 100%
TPC (mg GAE/100g)	65.38 ^{e}±0.82	81.20^{d}±1.64	95.23^{b}±1.72	87.47^{c}±2.20	102.90^{a}±2.5
TFC (mg quercetin /100g)	30.77^{d}±1.62	36.24^{c}±1.30	46.15^{b}±2.18	37.72^{c}±1.57	49.00^{a}±2.10
TAC	76.11^{e}±1.16	81.64^{d}±0.24	95.45^{b}±0.57	93.97^{c}±1.47	109.35^{a}±2.16
DPPH%	28.97^{b}±31.50	33.89^{b}±0.88	51.70^{a}±1.72	47.91^{a}±1.42	51.83^{a}±1.50

* Each value reflects the mean value of three ± SD replicates.
*Mean values of various letters in the same raw average at p≤0.05 stage is substantially different.

Complementary research by **Elhassaneen *et al.*, (2018)** documented a notable increase in TPC in biscuits containing 10% prickly pear peel (PPP), with values escalating from 111.87 in control samples to 158.98 mg EGA.100g$^{-1.}$ The same investigation reported a rise in antioxidant activity from 30.65% in control biscuits to 36.87% and 44.45% with 5% and 10% PPP incorporation, respectively.

Further supporting evidence comes from **Mahloko *et al.*, (2019)** observed an elevation in TFC from 17.0 mg/g in control biscuits to 33.74 mg/g following the addition of 4% prickly pear flours (PPF). These outcomes are congruent with the findings of **Elhassaneen *et al.*, (2016)** reported an increase in total phenolics content from 110.23 to 143.28 in crackers fortified with 5% prickly pear peel powder. Their study also noted an enhancement in antioxidant activity from 30.11% in control crackers to 38.14% and 42.07% with prickly pear peel powder incorporation.

3.5. Evaluation of cupcakes prepared by different levels of PPSP and PPSJ

3.5.1. Physicochemical Characterization

The data presented in Table (6) illustrates the physical characteristics of cupcakes prepared with PPSP and PPSJ. The results indicate that substituting wheat flour with PPSP at different levels (10% and 20%) led to an increase in both weight and volume of the cupcakes. Cupcakes produced using 50% and 100% PPSJ also showed enhanced weight and volume compared to the control sample.

According to the same table, cupcakes made with 100% PPSJ exhibited the highest measurements for weight (g), height (cm), and volume (cm^3), followed closely by those made with 50% PPSJ. In contrast, the cupcakes prepared with an addition of 20% PPSP displayed the lowest measurements. This reduction can be attributed to the decreased concentration of wheat flour, which in turn lowered the wheat gluten content, ultimately resulting in a decrease in volume. Our findings align with the research by **Parafati *et al.*, (2020)** stated that cakes containing up to 15% prickly pear peel flour showed a significant reduction in volume.

Table (6): Physical characteristics of prickly pear peel cupcake

Parameters	Control WF 100%	PPSP 10%	PPSP 20%	PPSJ 50%	PPSJ 100%
Weight (g)	$23.48^{d}\pm0.47$	$24.21^{c}\pm0.36$	$24.27^{c}\pm0.29$	$29.94^{b}\pm0.44$	$31.31^{a}\pm0.34$
Height (cm)	$3.10^{b}\pm0.36$	$3.08^{b}\pm0.15$	$3.06^{b}\pm0.09$	$3.34a^{b}\pm0.11$	$3.60^{a}\pm.10$
Volume (cm^3)	$57.51^{e}\pm0.47$	$59.84^{d}\pm38$	$60.61^{c}\pm14$	$66.14^{b}\pm25$	$69.10^{a}\pm0.17$
Specific Volume (cm3/g)	$2.43^{a}\pm0.03$	$2.45^{a}\pm0.04$	$2.47^{a}\pm0.03$	$2.19^{b}\pm0.01$	$2.22^{b}\pm0.02$

- Average of 3 replicates ± SD.
- Mean values of various letters in the same raw average at $p \leq 0.05$ stage is substantially different.

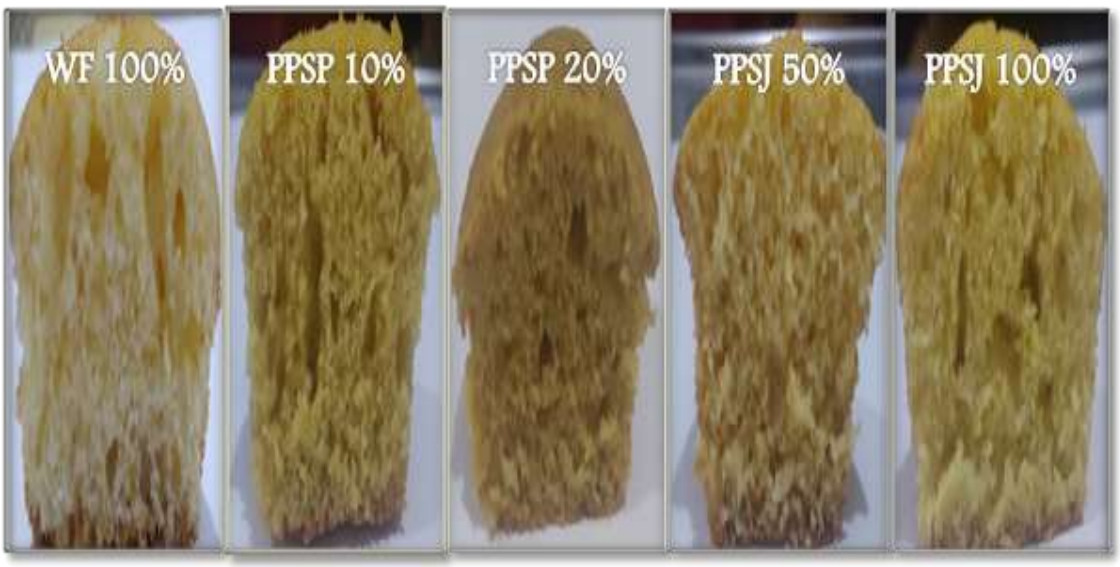


Photo (1): Cupcake prepared by prickly pear skin (powder and juice)

3.5.2. Color parameters

3.5.2.1. Color parameters of prickly pear peel cupcake (Crust)

The effect of PPSP and PPSJ addition on the cupcakes color parameters (L, a, b, ΔE, hue angle and Chroma) for cupcake crumb and crust are presented in Tables 7 and 8. Data are presented in Table (7) showed significant differences between the crust of the control cupcake and the cupcake fortified by PPSP and PPSJ.

Wheres the results of color parameters for cupcake crust showed decrease in L-value with increased of both redness (a-value) and yellowness (b-value) for all samples as compared to the control one. The control cupcake gave higher L* values compared to the samples supplemented with PPSP and PPSJ. A decrease in L* showed with the addition of PPSP and PPSJ (58.16, 54.53, 54.20, 50.77 and 40.67) in control, PPSJ 100%, PPSP 10%, PPSJ 50% and PPSP 20% respectively.

Cupcakes formulated with 20% of PPSP gave lesser L* value compared to cupcake with 10% PPSP due to their higher ratio of powder; which leads to the occurrence of maillard and caramelization reactions **(Ayadi *et al.*, 2009).** Our results were in agreement with **El-Beltagi *et al.*, (2023)** reported that the crust's brightness decreased as the level of prickly pear peel flour (PPPF) replacement increased.

There are a significantly differences in lightness, redness and yellowness values of all samples compared to control sample. So that was observed significantly differences in ΔE values and slightly differences in hue angle value.

Chroma is the indicator of color saturation and intensity. The higher the values are, the more desirable they are **(Albanese *et al.*, 2007 and Shih *et al.*, 2009).** In the same Table, data showed a significantly ($P < 0.05$) increase in chroma values in all samples compared to control sample; this could be due to the change in the values of a-value and b-value **(Sanaa *et al.*, 2017)**.

Table (7): Color characteristics of prickly pear skin cupcake (Crust)

Parameters	Control (WF100%)	PPSP 10%	PPSP 20%	PPSJ 50%	PPSJ 100%
L (Lightness)	58.16^{a}±2.08	54.20^{b}±1.5	40.67^{e}±2.1	50.77c±3.01	54.53^{b}±2.5
a (redness/greenness)	2.40^{c}±0.05	6.60^{b}±0.2	11.36^{a}±1.1	6.33b±1.05	3.27^{c}±0.5
b (yellowness/blueness)	25.27^{d}±1.5	34.47^{c}±0.70	38.60^{ab}±0.54	41.37^{a}±0.56	37.90^{b}±0.66
ΔE*	0	6.79	17.89	11.03	7.49
Hue angle**	82.33^{ab}±1.5	79.00^{b}±0.9	73.33^{c}±0.58	85.33^{c}±1.02	85.00^{a}±1.4
Chroma ***	25.47^{d}±0.85	35.10^{c}±0.7	40.23^{ab}±0.45	41.87^{a}±0.55	38.06^{bc}±0.95

* $\Delta E = [(L - Lo)^2 + (a - ao)^2 + (b - bo)^2]^{½}$. ** Hue angle = $[\tan^{-1} (b/a)]$. *** Chroma = $[(a^2 + b^2)]^{½}$.
Average of 3 replicates ± SD.
Mean values of various letters in the same raw average at p≤0.05 stage is substantially different.

3.5.2.2. Color parameters of prickly pear peel cupcake (Crumb)

Data in Table (8) observed significant differences between the crumb of the control cupcake and the cupcake fortified by PPSP and PPSJ. The control cupcake gave higher L* values compared to the samples supplemented with PPSP and PPSJ. A decrease in L* showed with the addition of PPSP and PPSJ (56.33, 51.17, 45.87, 42.73 and 34.83) in control, PPSJ 100%, PPSP 10%, PPSJ 50% and PPSP 20% respectively. Cupcakes formulated with 20% PPSP gave lesser L* value compared to cupcake with 10% PPSP; as well as, became darker due to their higher ratio of powder. On other hand, the addition of PPSP and PPSJ showed significantly increase in (a* values) and (b* values).

Our results were in agreement with **Ayadi *et al.*, (2009)** reported that cakes prepared with wheat flour fortified with cladodes powder had decreased in L* values compared with control sample with increasing level of cladodes powder**.** In addition, **El-Beltagi *et al.*, (2023**) reported that increased levels of prickly pear peel flour (PPPF) caused decreased in the lightness (L*). Also, our results in agreement with **Djeghim *et al.*,(2021)** reported that increased levels of dried prickly pear peel lead to increment in the yellowness (b*) and redness (a*) of the gluten-free bread crumb**.**

Table (8): Color characteristics of prickly pear skin cupcake (Crumb)

Parameters	Control WF100%	PPSP 10%	PPSP 20%	PPSJ 50%	PPSJ 100%
L (Lightness)	$56.33^{a}\pm1.22$	$45.87^{c}\pm1.09$	$34.83^{d}\pm1.45$	$42.73^{c}\pm1.7$	$51.17^{b}\pm1.6$
a (redness/greenness)	$0.6^{c}\pm0.002$	$0.66^{c}\pm0.001$	$6.63^{a}\pm0.5$	$2.63^{b}\pm0.8$	$0.96^{c}\pm0.088$
b (yellowness/blueness)	$25.50^{c}\pm0.55$	$33.33^{ab}\pm0.60$	$33.06^{ab}\pm0.49$	$30.70^{b}\pm0.50$	$36.6^{a}\pm0.70$
ΔE*	0	9.97	19.67	21.17	7.58
Hue angle**	$91.00^{a}\pm2.01$	$88.67^{b}\pm1.8$	$78.00^{d}\pm1.5$	$85.33^{c}\pm2.5$	$91.33^{a}\pm2.4$
Chroma ***	$25.53^{c}\pm1.08$	$33.33^{ab}\pm1.4$	$33.83^{ab}\pm1.1$	$30.80^{b}\pm1.25$	$25.53^{c}\pm2.01$

* $\Delta E = [(L - Lo)^2 + (a - ao)^2 + (b - bo)^2]^{1/2}$. ** Hue angle = $[\tan^{-1} (b/a)]$. *** Chroma = $[(a^2 + b^2)]^{1/2}$.
Average of 3 replicates ± SD.
Mean values of various letters in the same raw average at $p \leq 0.05$ stage is substantially different.

In the same Table, data showed slight differences in redness values of control, PPSP 10% and PPSJ 100% samples. Consequently, slight differences in ΔE values were observed. On other hand, there are a significantly differences in lightness and redness values of PPSP 20% and PPSJ 50% samples compared to control sample. So that was observed significantly differences in ΔE values. Under the results obtained results, it could be concluded that all samples product revealed acceptance in color values.

3.5.3. Organoleptic evaluation

One of the most important basic steps in developing food products is sensory evaluation; since it determines whether the product will be accepted or not. Data in Table (9) showed significant effect of added PPSP (10 and 20%) and PPSJ (50 and 100%) to cupcake formula on sensory proprieties such as (color, odor, taste, texture, shape and overall acceptability).

The results showed a significant difference ($P \leq 0.05$) in the color of the cupcake product with added PPSP and PPSJ (photo 1). The color of WF 100% had the highest score value (9.75) compared to all samples. The PPSP cupcakes color was shown to be the least liked by the panelists. The colour of cupcake product by PPSP and PPSJ is especially influenced by the presence of prickly pear skin used.

Broyart *et al.*, (1998) confirmed that the initial acceptance of baked products is much influenced by colour and prickly pear peel flour provide dark brown colour to the crackers.

According to **Tahir *et al.*, (2019)** the prickly pear skin is rich in natural pigments, as carotenoids and polyphenols (anthocyanins in particular) which responsible about a yellowish colour. The above facts explain why colour is likely to be affected primarily when prickly pear skin containing powder is used. Data were shown that the colour cupcake product by PPSP 10% and PPSP 20% was rated (7.90 and 7.60) respectively. Our result was in agreement with **Elhassaneen *et al.*, (2016)** reported that the colour of crackers product by prickly pear peel powder had (7.79) by the panelists.

It could be noticed that the odor of all prickly pear skin cupcake was affected significantly. While PPSP 10% mixture cupcake owned the highest odor value (8.55) compared to the other prickly pear skin cupcake. The composition of prickly pear flour showed a significantly higher concentration of fibre and ash compared to the WF, thus improving technological properties such as the aptitude to kneading, the flavor retention **(Bouazizi *et al.*, 2020).**

Table (9): Organoleptic evaluation of prickly pear skin cupcake

Parameters	Control WF100%	PPSP 10%	PPSP 20%	PPSJ 50%	PPSJ 100%
Color	$9.75^{a}\pm0.55$	$7.90^{c}\pm1.42$	$7.60^{c}\pm1.36$	$8.95^{b}\pm0.69$	$8.55^{b}\pm0.99$
Odor	$9.05^{a}\pm1.05$	$8.55^{b}\pm1.05$	$8.00^{b}\pm1.08$	$7.50^{c}\pm1.40$	$7.80^{c}\pm1.32$
Shape	$9.70^{a}\pm0.57$	$8.75^{b}\pm0.85$	$7.55^{c}\pm0.89$	$8.65^{b}\pm1.14$	$8.35^{b}\pm1.50$
Texture	$9.55^{a}\pm0.83$	$8.60^{b}\pm0.99$	$7.35^{d}\pm1.14$	$9.00^{ab}\pm1.03$	$8.25^{c}\pm1.29$
Taste	$9.40^{a}\pm1.05$	$9.05^{b}\pm0.94$	$7.85^{d}\pm1.66$	$8.50^{c}\pm1.10$	$7.45^{d}\pm1.19$
General acceptance	$9.50^{a}\pm0.76$	$8.90^{b}\pm0.85$	$8.05^{b}\pm1.05$	$8.55^{b}\pm0.95$	$7.75^{c}\pm1.12$

* Each value reflects the mean value ± SD.
* Mean values of various letters in the same raw average at $p\leq0.05$. stage are substantially different.

Also, significant difference ($P \leq 0.05$) was show in the texture of cupcake product by PPSP and PPSJ. The control sample has highest

texture score value (9.55); followed by cupcake produced by 50% PPSJ had score value (9.00), compare to all samples. However, the prickly pear skin cupcake was significantly different ($p \leq 0.05$) in overall acceptance compared to control cupcake and was shown to be the least liked by the panelists increase with increase the level of the addition (which had the lowest score) could be attributed to the taste of prickly pear juice, as commented by some of the panelists.

Many studies were in agreement with our result. For example, **Ashoush and Gadallah, (2011)** evaluated the effect of mango peels powder at different replacing levels (5-20%) on sensory properties of biscuits; and reported that the acceptable biscuits with mango flavor were obtained by incorporating up to 10% mango peels powders. Also, **Ahmed, (2016)** reported that the acceptable breads product were obtained by incorporating up to 5% mango peels powder. Also, **Elhassaneen *et al.*, (2016)** confirmed that prickly pear peel incorporated crackers by 5% doesn't effect on their overall quality.

4. Conclusion

This study demonstrates the nutritional value of the cupcakes samples fortification with (PPSP and PPSJ); Wheres the chemical composition showed that they are a good source of dietary fibers and increased in bioactive compounds (TPC, TFC and TAC) .Also, The findings suggest that cupcakes product have carbohydrates and Kcal lower than the control sample; subsequently increased their properties as bio-functional foods. And the organoleptic evaluation of products incorporated by 10% PPSP and 50% PPSJ observed best overall acceptance. So, that these results may contribute develop and market such these products.

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تعزيز النشاط الحيوي الوظيفي للكب كيك بإضافة مسحوق و عصير قشور التين الشوكي العضوى

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في الآونة الأخيرة، زاد الاهتمام بإنتاج الأغذية الوظيفية باستخدام مصادر طبيعية غنية بالمركبات النشطة بيولوجيًا لتعزيز الخصائص الوظيفية للمنتجات الغذائية. التين الشوكي هو مصدر غني بالمواد الكيميائية النباتية. لذلك، استهدفت الدراسة الحالية أولاً تحديد التركيب الكيميائي التقريبي والخصائص الفيزيائية لمسحوق قشر التين الشوكي وعصير قشر التين الشوكي ودقيق القمح بالإضافة إلى ذلك، تم تحديد إجمالي المركبات الفينولية وإجمالي الفلافونويد والقدرة المضادة للأكسدة الكلية. ثم إنتاج وتقييم الخصائص الحسية لكب كيك مبتكر بنسبة (50 و100٪) من عصير قشر التين الشوكي و (10 و20٪) من مسحوق قشر التين الشوكي. أشارت النتائج إلى أن مسحوق قشر التين الشوكي يحتوي على أعلى نسبة من الألياف والرماد يليه عصير قشر التين الشوكي ثم دقيق القمح. أدى إضافة عصير قشر التين الشوكي بنسبة (50 و100٪) لتركيبه الكب كيك إلى تأثير كبير على الرطوبة، كما أدى إضافة مسحوق قشر التين الشوكي بنسبة (10 و20٪) إلى انخفاض في محتوى البروتين والكربوهيدرات لكنه أدى إلى زيادة محتوى الألياف والرماد مقارنة بكب كيك دقيق القمح. سجل كب كيك عصير ومسحوق قشر التين الشوكي بمستويات مختلفة أعلى محتوى من المركبات الفينولية وإجمالي الفلافونويد والقدرة المضادة للأكسدة الكلية مقارنة بكب كيك دقيق القمح .كما أشارت البيانات إلى أن زيادة مستويات عصير ومسحوق قشر التين الشوكي أدت إلى زيادة المركبات الكيميائية النباتية خاصة بالنسبة لكب كيك عصير قشر التين الشوكي(100%) التي سجلت أعلى محتوى من المركبات الفينولية وإجمالي الفلافونويد والقدرة المضادة للأكسدة ليكون 102,90 مجم حمض الجاليك/ 100 جم و 109,35 و 51,83 على التوالي، يليه كب كيك مسحوق قشر التين الشوكي(20%) ليسجل 95,23 مجم حمض الجاليك/ 100 جم و 95,45 و 51,70 على التوالي. كما تظهر نتائج التقييم الحسي أن إضافة نسبة تصل إلى 10% من مسحوق قشر التين الشوكي و50% من عصير قشر التين الشوكي للكب كيك كانت مقبولة بشكل جيد ولا تؤثر على جودتها الإجمالية. لذا، يمكن استخدامها في إنتاج كب كيك وظيفي وصحي وبالتالي يمكن تسويق مثل هذا المنتج.

الكلمات المفتاحية: عائلة التين الشوكي؛ المنتج الثانوي؛ المركبات النشطة بيولوجيًا؛ القيمة الغذائية .