



Innovative Use of Prickly Pear Peel , Cladodes and fruits in Jelly Candy Formulation: physiochemical, antioxidant, safety, nutritional and sensory evaluations.

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ABSTRACT

Many valuable parts of plants are often discarded despite their richness in antioxidants and nutrients that offer health benefits . Recently , importance of plant waste becomes increasingly evident. Jelly candies , widely consumed by people of all ages , offer no nutritional value ,contain harmful additives , high sugar leading to various health problems. Prickly pear parts (fruit , peel and cladodes) rich in antioxidant , many nutrient , low in calorie, stands as a forgotten treasure . Therefore , this study aims to innovate healthy and nutritionally jelly candy enriched with bioactive compounds that can serve as functional food. Three jelly candies were produced from prickly pear (fruit ; mix of fruit , peels and cladodes at ratio 1:1:1 sweated either with sugar or honey). Sensory evaluation , gross chemical analysis , physiochemical properties , polyphenols & flavonoids contents , antioxidants activity and cytotoxicity were detected . Sensory evaluation demonstrated strong acceptance of mix candies with no significant difference across samples. Chemical composition indicated significant level of carbohydrate , protein , fiber and minerals , enhanced by inclusion of peels and cladodes . Hardness of jelly candy increases during storage period ensuring product stability. polyphenols in samples enriched with peels and cladodes were more than triple that found in sample with fruit only , flavonoids were also higher in such samples contributing to high antioxidant activity. Cytotoxicity confirmed the absence of harmful effects ,highlighting the product's safety and potential to use as a functional food.

Keyword : opuntia Ficus , candies , nopales ,healthy snack, byproducts.

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INTRODUCTION

Jelly candies , which are widely consumed provide negligible nutritional benefits and often contain synthetic components (artificial food colors ,flavors as well as chemical preservatives) that cause significant health risks to consumers .

Gelling agents, sucrose, glucose syrup, acids, flavorings, and colorants are used in confectionery hydrogel products manufacturing .The high sugar content and low nutritional value of confectionery products are questionable for their association with cardiovascular diseases, hypertension, diabetes and obesity.

Numerous studies have confirmed that fruits , cladodes as well as peel of prickly pear cactus are valuable sources of nutrients and phytochemicals and possess high antioxidant activity, as such pear is recognized for its contribution to a healthy diet and its richness in health-promoting compounds (**Tunç et al , 2025 &Kofan et al , 2024**).

Some medicinal properties of the cactus include its antioxidant , anti-inflammatory , diuretic , antidiabetic , antihypercholesteremic and anticarcinogenic effects (**Farag et al , 2020**).

Antioxidant from natural food have gotten high attention due to their protection against cyto and genotoxicity of cell (**wang et al , 2023**).

Researcher suggested that prickly pear parts can serve as functional foods , offering an excellent source of nutrients such as protein , ash , fibers and active compounds that benefit human health . (**Shoukat et al , 2023**).

Today , the nopal cladodes are gaining popularity as a vegetable due to their remarkable ecological adaptability . More significantly their chemical constituents provide a high potential for use as functional foods because of their nutritional and health benefits such as hypercholesterolemia , treatment of metabolic syndrome (obesity, diabetics and hypertension) as well as increase bone density (**Hernandez-Becerra et al , 2022 & Barba et al , 2022**). Cactus pear peel powder decreased serum glucose, triglyceride and LDL cholesterol levels in rats (**Arias-Rico et al , 2025**).

prickly pear (*Opuntia ficus indica*)fruits are rich in antioxidants and also contain nine vitamins (**Louppis et al , 2025**)

Morover cladodes ethanol extract have demonstrated a cytotoxic effect against cancer cell (**D'angeli et al , 2024**).

Recently , there, has been many research focused on recycling horticultural by-products, rich in bioactive compounds, for food fortification as quantities of waste represent economic and environmental challenges . Recycling bio-waste can transform it into value-added products. Cactus peels that represent 30 -50 % of total fruit weight or more (according to species) , are source of protein , dietary fibers as well as variety of antioxidants (**Timpanaro and Foti , 2025 and Le Rose et al , 2025**)

Many products were derived from the prickly pear parts and by products such as juice ,cookies , cakes , candies , jams , jellies , and bakery products , such products were highly accepted by panelists .(**Kallel et al , 2024 ; Barba et al , 2022 & Peralta et al , 2024**).

Given their nutritional value , prickly pear peel and cladodes are promising food source for addressing these health challenges.

This growing demand highlights the need for developing confectionery products that combine appealing sensory attributes with improved nutritional and functional properties.

This study aimed :

1-To develop high nutritive value jelly candy using prickly pear fruits as well as peel and cladodes .

2-To evaluate the sensory attributes, physiochemical properties as well as texture stability of the developed formulations during storage.

3-To assess antioxidant, flavonoids content and phenolic components screening

4-To assess the potential of using fruit by products in a healthy functional food , thereby recycling , reducing waste and improving environmental value.

5-To ensure the safety of the developed product by evaluating its potential cytotoxic effect on human cells.

MATERIALS AND METHODS

2.1.Preparation of raw materials:

Prickly pear fruits were obtained from local market, whereas, fresh cladodes were collected directly from nearby farms. All materials were well washed, and all thorns were carefully removed. The fruits were peeled and each part (fruits, peel and cladodes) was separately cut into small pieces and homogenized. The resulted pulp were strained (not filtered) to remove seeds while preserving natural fiber content in the mixture.

2.2. Preparation of candy jelly:

Three formulations of jelly candies were made:

- 1- Fruit control sample B :Jelly made solely from fruit pulp only sweetened with 20 g sugar /100g pulp
- 2- Mixed samples: two candies were made from a mixture of fruits, peel and cladodes pulps
- 3- in a ratio of 1:1:1 sweetened either with sugar C (20 g/100g) or 20 g /100g honey A (to provide a healthier alternative candy).

For all formulations, the mixture (juice or blend) was gently heated in a water bath with the addition of sugar where applicable and 0.3 g citric acid. Gelatin powder (20 gram) pre-dissolved in 20ml of the mixture was added for every sample during heating . The process continued until the mixture reached a final total soluble solids (TSS) content of 55-60% measured by refractometer, pH was also measured using pH meter. The jelly was then poured into containers and stored in a refrigerator for 24 hours, after which it was cut into uniform shapes.

Candies were then stored in well package glass lock for 2 weeks in order to assess change in texture.

2.3. Sensory evaluation:

Sensory evaluation for the three prepared candies was conducted at zero time. Taste, color, odor, texture and overall acceptability were evaluated through score over 10.

2.4. Chemical analysis:

2.4.1. Gross chemical analysis

Was conducted out of which moisture ,protein , total fat , fiber and ash were determined according to AOAC 2016. Carbohydrate was calculated by difference. Energy yield was also calculated.

2.4.2. Total Phenolic, total flavonoids and antioxidant activity determination:

Total phenols in jelly candies A,B and C were conducted as described by **Arno us et al (2001)** . Total flavonoids was assessed according to **Chang et al, (2002)**

Antioxidant activity was measured by (DPPH) 1,1- diphenyl -2- picryl – hydroxyl following methods described by Brand – **Williams et al , (1995)**

2.5. Texture

The hardness of jelly candies was determined using a Texture Analyzer instrument (Model 4301, Instron Corp., and Canton, MA, USA) according to **Delgado and Bandon (2015)**, the force was recorded in Newtons (N).

2.6. Cytotoxic effect on normal human cell:

Effect on cell toxicity was carried in Nawah lab, Cairo.

2.6.1. Cell culture HSF:

Human Skin Fibroblast was obtained from Nawah Scientific Inc., (Mokatam, Cairo, Egypt).

2.6.2. Cytotoxicity assay:

Cell viability was assessed according to **Saehan et al (1990) and Allam et al (2018)**

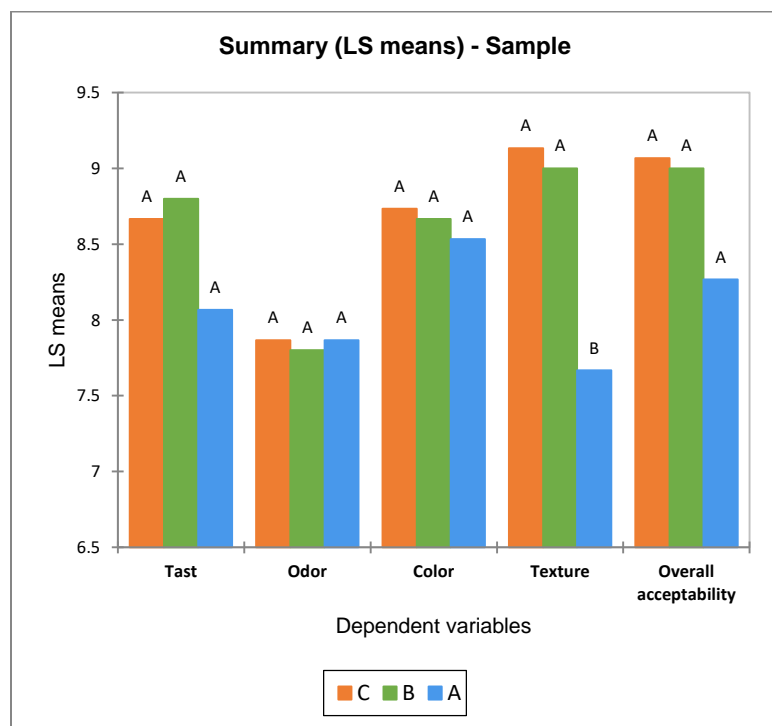
By SRB assay. Aliquots of 100 μL cell suspension (5×10^3 cells) were in 96-well plates and incubated in complete media for 24 h. Cells were treated with another aliquot of 100 μL media containing drugs at various concentrations. After drug exposure, cells were fixed by replacing media with 150 μL of 10% TCA and incubated at 4 $^{\circ}\text{C}$ for 1 h. The TCA solution was removed, and the cells were washed 5 times with distilled water. Aliquots of 70 μL SRB solution (0.4% w/v) were added and incubated in a dark place at room temperature for 10 min. Plates were washed 3 times with 1% acetic acid and allowed to air-dry overnight. Then, 150 μL of TRIS (10 mM) was added to dissolve protein bound SRB stain; the absorbance was measured at 540 nm using an Infinite F50 microplate reader (TECAN, Switzerland).

2.7. Statistical analysis:

Significance was assessed .ANOVA test was also conducted. (**Milson 2016**)

RESULTS AND DISCUSSION

Sensory evaluation of the three gelatin candy samples (A mix of fruit, peel and cladodes with honey , B control (prickly pear fruit only) and C mix of fruit , peel and cladodes with sugar) are presented in table (1) and figure (1).



Fig(1): sensory evaluation of the three jelly candies:A (made from fruit , peel and cladodes at ratio 1:1:1 with honey)B (from prickly pear fruit served as control) and C (made from fruit , peel and cladodes at ratio 1:1:1 with sugar) .

Table (1) : sensory evaluation of the three different jelly candies (mean and standard deviation).

| Attribute / Sample | Taste | Odor | Color | Texture | Overall acceptability |
|--------------------|------------|------------|------------|-------------|-----------------------|
| A (mix with honey) | 8.07±1.62a | 7.87±2.03a | 8.53±1.12a | 7.67±1.29b | 8.27±1.44a |
| B(fruit control) | 8.8±1.014a | 7.80±1.52a | 8.67±0.72a | 9.00±0.84a | 9.00±0.93a |
| C(mix with sugar) | 8.67±0.62a | 7.87±1.36a | 8.73±0.79a | 9.133±0.83a | 9.07±0.70a |

Results revealed that all samples were highly acceptable . Statistical analysis indicated that texture of sample A (mix with honey) showed a significant lower value compared with other samples, the lowest score in texture may be due to the high moisture content of honey that resulted in a noticeable softening of the texture and a decrease in the structural integrity and cohesiveness of the sample, which affected also overall acceptability. No significant different (P>0.05) were noted between samples concerning taste , odor ,color and over all acceptability

Table (2): Correlation analysis of sensory evaluation attributes:

It is honored to point out that candies made from fruits , peel and cladodes at a ratio 1:1:1 either with sugar (C) or honey (A) had scores very closed to that of candy made from fruit only in all sensory attributes (except for texture in sample A) .

Although peels and cladodes are typically regarded as waste material, their inclusion resulted in good sensory quality candy.

The results suggest that all formulations were acceptable, but minor differences among samples could be further explored through ANOVA test to identify significant differences in individual attributes

Data regarding correlation analysis of sensory evaluation attributes are presented in table (2).

Table (2): Correlation analysis of sensory evaluation attributes:

| | SampleA | SampleB | SampleC | Taste | Odor | Color | Texture | Overall acceptability |
|-----------------------|---------|---------|---------|---------|---------|---------|---------|-----------------------|
| SampleA | 1 | -0.5000 | -0.5000 | -0.2694 | 0.0098 | -0.0900 | -0.5587 | -0.3306 |
| SampleB | -0.5000 | 1 | -0.5000 | 0.1751 | -0.0196 | 0.0180 | 0.2394 | 0.1437 |
| SampleC | -0.5000 | -0.5000 | 1 | 0.0943 | 0.0098 | 0.0720 | 0.3192 | 0.1869 |
| Taste | -0.2694 | 0.1751 | 0.0943 | 1 | 0.6240 | 0.5492 | 0.4063 | 0.8035 |
| Odor | 0.0098 | -0.0196 | 0.0098 | 0.6240 | 1 | 0.5790 | 0.3305 | 0.6136 |
| Color | -0.0900 | 0.0180 | 0.0720 | 0.5492 | 0.5790 | 1 | 0.3361 | 0.6156 |
| Texture | -0.5587 | 0.2394 | 0.3192 | 0.4063 | 0.3305 | 0.3361 | 1 | 0.6023 |
| Overall acceptability | -0.3306 | 0.1437 | 0.1869 | 0.8035 | 0.6136 | 0.6156 | 0.6023 | 1 |

From this table it could be declared that all sensory attributes are positively correlated , which indicate that improvement in one attribute (taste , color ,...) tends to enhance overall acceptance . The strongest correlation between taste and overall acceptability ($r=0.8035$) confirms that taste is the primary sensory driver of acceptability in this study .The correlation matrix highlights that the multidimensional nature of other sensory perception were attributes such as texture and color thus along with taste should be prioritized in product development.

Due to the high nutritional and health benefits of prickly pears parts, they are used by many researchers to fortify many products .In a study conducted by **Le Rose et al 2025**, cheesecake fortified by prickly pear peels, juice and pomace showed acceptability closed to control.

In another study , Jelly made from different kind of prickly pear fruit were low in calories and suitable for diabetic patients and all formulations were positively accepted by judges (**Chacon-Garza et al 2020**).

It is worthy to mention that experimental candy products represent shifting of unhealthy popular candy free from health or nutritional benefit to high nutritive, healthy as well as highly accepted product . Moreover , these products are made from combination of both fruit and by-products (peel and cladodes) , that not only reduce environmental pollution but also offer high nutritive value and health promoting effect.

Gross chemical analysis of jelly candies was analyzed. Results were presented in table (3). From this result it could be noted that moisture content ranged from 42.5 (in sample B) to 46.3 (in sample A) . Protein content were almost equal in sample A & C (20.6 vs 20.9 g) while was only 18.8 g in sample B . High fiber (4.8 and 5.1) and ash (1.9 & 1.7 respectively) were noted in samples A & C with peel and cladodes vs. 1.6 & 0.89 in sample B made from fruit only.

Table (3) : Gross chemical analysis for jelly candies g/ 100 g fresh weight:

| Sample Component | Jelly candy with Honey A | Jelly candy with fruit only B | Jelly candy with sugar C |
|-------------------------|-----------------------------|----------------------------------|-----------------------------|
| Moisture | 46.3 | 42.5 | 44.1 |
| Fat | 0.25 | 0.24 | 0.25 |
| Protein | 20.6 | 18.8 | 20.9 |
| Fiber | 4.8 | 1.6 | 5.1 |
| Carbohydrate | 26.15 | 35.97 | 27.95 |
| Ash | 1.9 | 0.89 | 1.7 |
| Calculated energy yield | 189.25 | 221.24 | 197.65 |

Carbohydrate content was higher in sample B (35.97 g), compared with 26.15 & 27.95 g in A and C samples respectively.

Caloric content was closed in samples A & C (189.25 & 197.65 calories / 100 g respectively) while was slightly higher in sample B (221.24 calories / 100 g).

It could be declared that sample A and C jelly candy , produced primarily from part of plants that are considered as by- products (peel and cladodes that represent two third of total ingredients), resulted in low calorie , high fiber and minerals products as well as its health benefit.

In a study conducted by Ali, et al (2021) jelly candies fortified with beetroot and strawberry, had moisture content ranged from 34 -36.5 compared with 39.13% in control while ash content fluctuated between 0.77 and 0.95%.

Shoukat, et al (2023) declared that prickly pear cladodes contain 64 – 71 % carbohydrates , 18 % fiber , 19- 23.5 % ash , 4-10 % protein and a 1-4% fat on dry weight basis.

With regard to the chemical composition of peel, a study conducted by Arias-Rico et al(2025) noted that peel of purple prickly pear contain : dietetic fiber (43%), protein (2.78%) , carbohydrates (38.10%), ash (9.77%) and lipids (1.75%).

In another study conducted by Badr et al 2017 on prickly pear , they found that protein content of peel was 4.75% that include 15 amino acids of which seven were essentials. They found that Peel contain also carbohydrate (59.25%) , fibers and minerals like Ca , Fe , Zn ,P and CU .

Table (4): Cytotoxicity effect of samples A and C on human cell:

| Conc. | Viability in sample A | | | Mean STD | Viability in sample C | | | Mean STD |
|-------|-----------------------|--------|--------|------------------|-----------------------|-------|-------|-------------|
| | 1 | 2 | 3 | | 1 | 2 | 3 | |
| C | 100 | 100 | 100 | 100±0 | 100 | 100 | 100 | 100±0 |
| 0.01 | 101.53 | 98.59 | 98.59 | 99.59± 1.369 | 94.10 | 96.34 | 98.37 | 96.27±1.74 |
| 0.1 | 96.87 | 100.67 | 100.67 | 99.22± 1.679 | 93.01 | 94.56 | 97.55 | 95.04±1.88 |
| 1 | 101.82 | 95.99 | 95.99 | 98.40± 2.483 | 92.75 | 97.02 | 93.42 | 94.40±1.87 |
| 10 | 66.19 | 93.32 | 93.32 | 96.50± 2.420 | 91.63 | 95.71 | 93.69 | 93.68±1.66 |
| 100 | 88.09 | 89.10 | 89.87 | 88.69± 0.8366 | 85.14 | 90.27 | 88.49 | 87.97±2.12 |
| Blank | Control average | | 1.316 | | Control average | | 1.369 | |

To ensure safety on human cell toxicity of jelly candy products (with honey and with sugar) , cell viability of Human Skin Fibroblast exposed to jelly candy extract (A and C) was assessed , Data on cell viability was presented in table (4) and figure (2).

From these results it could be mentioned that for both formulation maintained high cell viability (represented as mean and standard deviation) across all tested concentration , even at lowest concentration . Mean viabilities in A were 99.59 ;99.22 ; 98.40 ; 96.50 and 88.69% at concentration 0.01 ;0.1 ; 1 ;10 and 100 respectively while for sample C at the same concentration , the corresponding viability were 96.27 ; 95.04 ; 94.40 ; 93.68 and 87.97 % .ISO 10993-5 and common cytotoxicity practice stated that materials which yield viability $\geq 70\%$ compared with control are considered non-cytotoxic , accordingly it is worthy to mention that at condition and concentration tested , our jelly candy products made from materials considered as waste (cladodes and peel) are safe and does not possess any cytotoxic effect on normal cell.

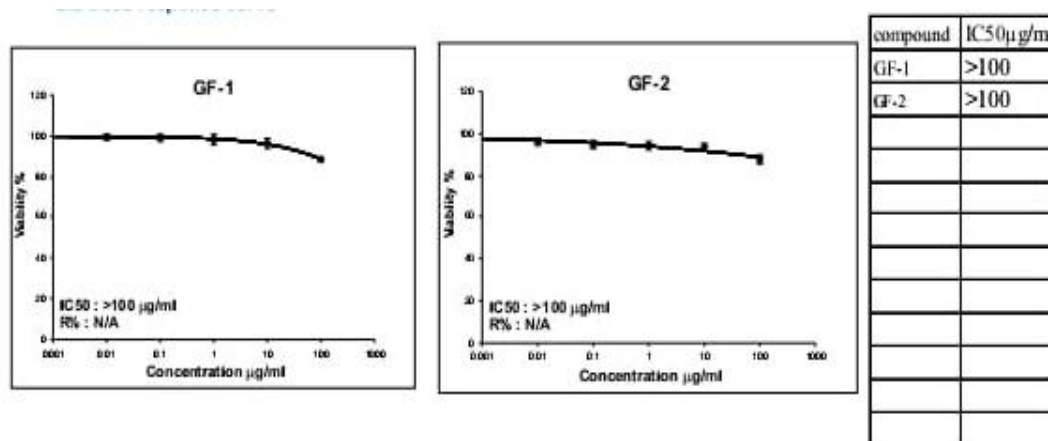


Fig (2):Cytotoxicity effect of samples A(GF-1) and C (GF-2) Dose response curve.

Polyphenols possess a great antioxidant activity , which have multi health benefits like anticancer , anti aging , anti-inflammatory , antidiabetic effect as well as help to protect from chronic diseases .(Koufan et al 2024)

Data regarding total polyphenolic contents, total flavonoids and antioxidant activity are presented in table (5)

From this table it could be mentioned that jelly candy products made from prickly pear fruit pulp, peel, and cladodes (1:1:1 mixture) revealed a relatively high concentration of total polyphenolics and flavonoids, confirming the strong antioxidant potential of the combined product. The mean total phenolic content in both products with honey (A) and sugar (C) are 253.2 & 231. 58 mg GAE/100 g fresh weight in respective order compared with only 68 mg GAE/100 g in jelly candy made from fruit

Regarding total flavonoids content, values were 67.51 and 63.23 mg QE/100 g fresh weight in A & C respectively, these values equal about two fold that found in B (fruit only).

Table (5): Total polyphenol (mg GAE /100 g), flavonoids (mg QE/100g) and antioxidant activity(%DPPH inhibition) in jelly candies:

| Sample / component | A (mix with honey) | B(fruit only) | C(mix with sugar) |
|---------------------------------------|---------------------|---------------|--------------------|
| Total polyphenolic mg GAE /100 g | 253.2 | 68 | 231.58 |
| Total flavonoids mg QE/100g | 67.51 | 34 | 63.23 |
| Antioxidant activity %DPPH inhibition | 63.81% | 45 | -58.25% |

Antioxidant activity (%DPPH inhibition)was slightly higher in jelly candy with honey (A) than that with sugar(C) 63.81 , 58.25 in respective order comparing with 45 in candy made from fruits only.

It is worthy to mention that candies made from fruit , peel and cladodes 1:1:1 formulation provides a balanced and sustainable source of antioxidants and phytochemicals, supporting its application in health-promoting food products and in reducing agricultural waste through full fruit utilization.

Our results are in agreement with those obtained by Farag , et al (2020), who declared that both cactus pear fruits and peels contain high amount of antioxidants and that antioxidant activity of fruit was almost twice that found in pear , apple , banana and tomato .They also declared that flavonoids and coumarins found in cactus fruits mediated high antioxidant effect although the lower content of such antioxidants.

Prickly pear cladodes are also rich in polyphenols and flavonoids (D’Angeli et al 2024 and Koufan et al 2024)

Another study conducted by Touati et al 2025 found that *O. ficus-indica* seeds extract was rich in antioxidant compounds and exhibited high antioxidant and anti-inflammatory capacity.

Table (6): texture of jelly Candies: A (mix with honey) , B (fruit only) and C (mix with sugar) at zero time and after 1 & 2 weeks expressed as Newton (N).

| Time / sample | Zero time | 1 week | 2 weeks |
|---------------|-----------|--------|---------|
| A | 22 | 39 | 42 |
| B | 30 | 42 | 52 |
| C | 35 | 50 | 55 |

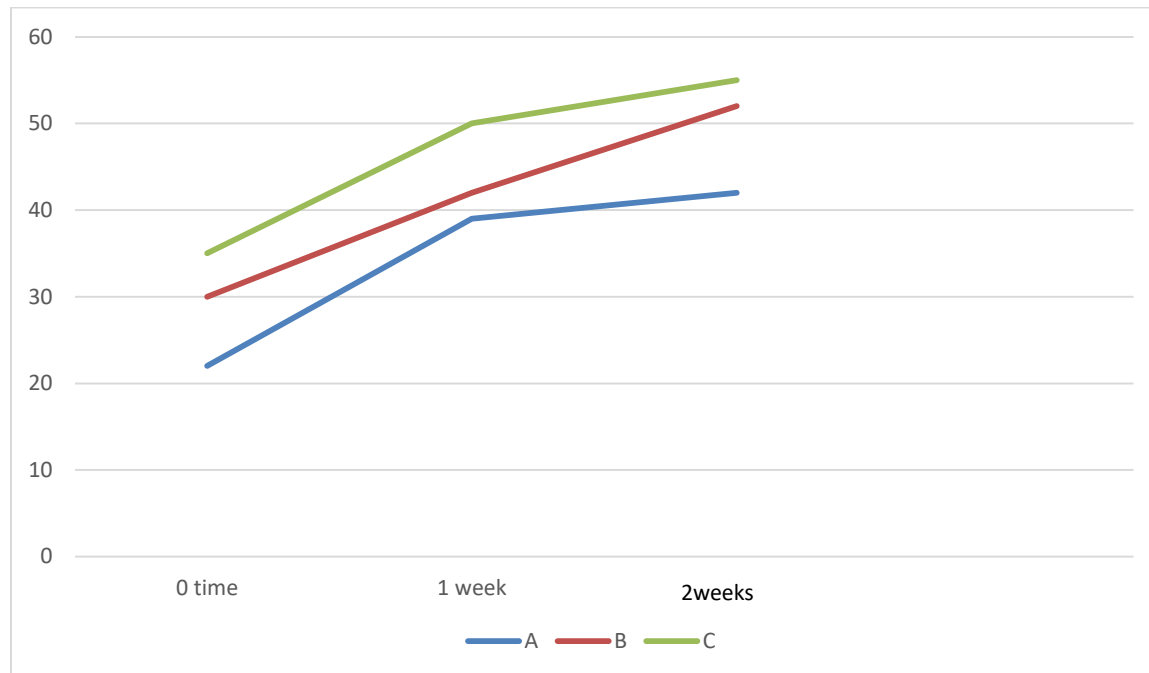


Fig (3) texture of jelly candies :A (mix with honey) , B (fruit only) and C (mix with sugar) at zero time and after 1 & 2 weeks.

The results clearly showed that the hardness of jelly candy increases progressively during the storage period for all samples . This trend indicates that jelly candy undergoes structural changes over time that affect its texture.

Results revealed that sample A had the lowest hardness (22N) while sample C had the highest (35N).

After one week , all samples exhibited a noticeable rise in hardness which ranged from 39 – 50 N, after two weeks , the hardness continued to rise till reached 42 , 52 and 55 in A B and C respectively.

Sample C consistently showed the highest hardness throughout the storage period , suggesting a more stable gell structure.

Three physiochemical mechanisms explain such increase, which include: gradual moisture loss during storage (one of the main contributors to increased hardness) leading to decrease water content ,increase concentration of soluble solids and a firmer and more rigid texture (**Nabeshima and Groomann 2001**) .

Secondly, strengthening of the gel network, gelatin – based products continue to undergo network rearrangement after preparation over time , thus the candy becomes more resistance to deformation,

Finally, sugar structural changes making jelly matrix more organized during storage which may improve internal cohesion and firmness. (**Zhou et al 2021**).

Table (7): Physiochemical parameters of jelly candies:

| Parameter Sample | Moisture% | Total solids(TS)% | pH |
|---------------------|-----------|-------------------|-----|
| A | 46.3 | 53.7 | 4.6 |
| B | 42.5 | 57.5 | 5.3 |
| C | 44.1 | 55.9 | 4.9 |

The physiochemical evaluation of the jelly candy samples revealed noticeable differences in moisture content, total solids and pH , which directly influence the quality texture and stability of the final products.

Moisture content varied among the samples ranging from 42.5 in sample B to 46.3 in Sample A . Higher moisture content generally contributes to softer texture but may also reduce shelf life due to increase susceptibility to microbial growth and stickiness.

Similarly total solids TS % showed an inverse trend to moisture with sample B having the highest TS (57.5%) whereas sample A showed the lowest (53.7%) .

Regarding pH, the values ranged between 4.6 & 5.3.

CONCLUSION

It's the first study to combine prickly pear peel and cladodes (considered by waste) with fruit that resulted a jelly candy rich in flavonoids , polyphenols , fibers , minerals and possess Hight acceptability . Safety was also ensured by cytotoxic test , physiochemical characteristic ensure stability .

This product represent a shifting of jelly candy from harmful with no nutrition value to a delicious , high nutritive quality candy.

these benefits make them proper to use as functional food due to their nutritional enhancement side to their role in waste reduction .

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