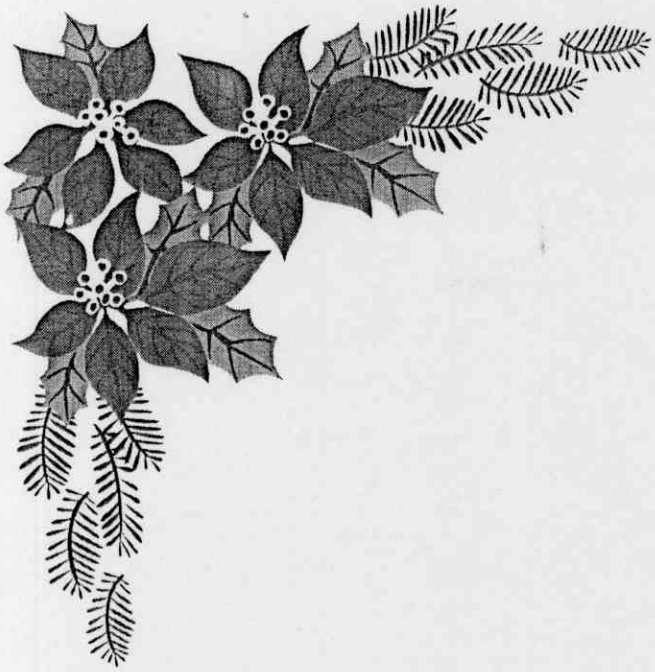
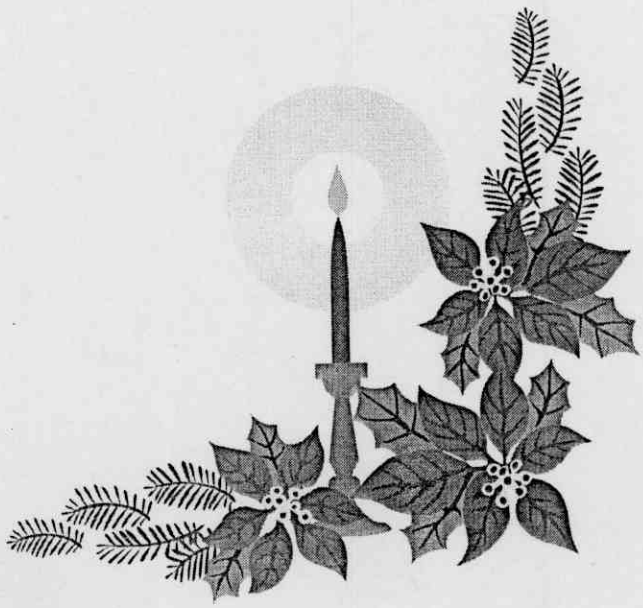


SUMMARY & CONCLUSION



V. SUMMARY

Prickly pear (*Opuntica ficus indica*) have been grown in Egypt for many years ago, especially in sandy areas. So, the production of prickly pear fruits increased in recent years due to the increase in production area. The prickly pear fruits are also very susceptible to microbial spoilage because of the low acids and high sugar content of the pulp so that the storage life of the fruit in the fresh state is limited and the available research on prickly pear still very little and the limited consumption still as a fresh fruits. Thus this study was planned to study the following points:

1- To study the chemical composition of prickly pear pulp and freezing effect and storage at -18°C on the chemical composition, microbiological and sensory evaluation.

2- Determination of D and Z values of pectin methylesterase enzyme and evaluation of the thermal processing.

3- Study the possibility of producing some products from the prickly pear pulp such as juice (Nectars) and concentrated prickly pear.

4- To study the rheological properties and effect of temperature on pulp, juice and concentrates of prickly pears.

The obtained results are as following:

Part I: Frozen storage of prickly pear pulp:

1- General and approximate chemical composition of prickly pear fruits:

The general composition of prickly pear fruits was 56.88% pulp, 38.4% peels and 4.72% seeds, while the proximate chemical composition of prickly pear pulp was 86.79, 0.75, 0.32, 0.38, 0.44 and 11.32% for moisture, crude protein, ether extract, crude fiber, ash and total carbohydrate, respectively.

2- Chemical composition of raw prickly pear pulp:

Chemical composition of prickly pear pulp for total solids; total soluble solids (°Brix), acidity (as citric), pH value, total sugars, reducing sugars and non-reducing sugars were 13.21%, 11.53°Brix, 0.072%, 5.72; 10.86%; 10.75% and 0.110%, respectively. Ascorbic acid (Vit. C) carotenoids, the total pectic substances, water soluble pectin, ammonium oxalate soluble pectin, acid soluble pectin and sugar/acidity ratio were 13.7 mg/100g, 0.83 mg/kg, 0.49%, 0.11%, 0.31%, 0.07% and 150.83, respectively. Mineral contents of prickly pear pulp were calcium (Ca) 333.0, magnesium (Mg) 183.6, phosphorus (P) 134.9, sodium (Na) 80.3, potassium (K) 838.9 iron (Fe) 6.43 and copper (Cu) 0.184, mg/kg of prickly pear pulp.

3- Microbiological load of raw prickly pear pulp:

The total plate count, gram negative, total coliform and *E. coli* of prickly pear pulp determined by the normal methods were $5.4x10^4$, $3.2x10^4$, $1.8x10^3$ and $3.9x10^2$ cfu/g, respectively. Also the same analysis as carried out by the Four Culture Methods

(FCM) were $8.1x10^4$, $1.02x10^4$, $2.56x10^3$ and $3.2x10^2$ cfu/g, respectively. The Count of yeasts and molds by normal methods was $1.15x10^3$ cfu/g.

4- Effect of pasteurization, freezing and storage at -18°C on the chemical composition of prickly pear pulp:

Pasteurization of prickly pear pulp at 85°C/3 min reduced moisture content from 86.79 to 85.84%, while the ether extract, protein, crude fiber, ash and total carbohydrate were increased slightly after pasteurization. On the other hand, after 12 months of frozen storage, the same components were slightly reduced except carbohydrates which were increased.

The pH value decreased slightly from 5.7 to 5.52, while acidity increased from 0.074% to 0.081% (as citric acid) after 12 months of storage period. The total solids and total soluble solids were 14.16 and 12.65 at the beginning of storage and were increased at the end of storage period to 14.98% and 13.32°Brix, respectively.

Vitamin C content of PP pulp was 13.70 mg/100 g and it was reduced to 4.91 mg/100 g after pasteurization. Also, carotenoids content reduced from 0.83 to 0.74 mg/kg, respectively. Vitamin C was decreased to 1.10 mg/100 g and carotenoids content were decreased to 0.58 mg/kg after 2 months storage period. The total sugar, reducing sugar and non reducing sugar were decreased at the end of frozen storage. Mineral content for calcium, magnesium and phosphorus of PP pulp were increased after pasteurization to 356.2, 196.4 and 148.7 mg/kg. Also, sodium, potassium, iron and copper, changed to 83.17, 888.1, 6.75 and 0.193, mg/kg after pasteurization, respectively.

Minerals contents of prickly pear was slightly reduced after 12 months of freezing storage at -18°C.

5- Effect of freezing and storage on microbiological load of prickly pear:

The obtained results showed that the total plate count and gram negative count in raw prickly pear pulp were $5.0x10^4$ and $3.2x10^4$ cfu/g and which were decreased to $1.6x10^4$ and $1.12x10^4$ cfu/g after pasteurization at 85°C/3 min and became $1.0x10^4$ and $0.9x10^4$ cfu/g at the end of frozen storage by using normal method (A), while by four culture method (B) the count numbers were $8.1x10^4$ and $1.02x10^4$ cfu/g for raw prickly pear pulp. After pasteurization the counts became $3.16x10^3$ and $1.29x10^3$ cfu/g, while it reached to $2.00x10^3$ and $1.29x10^3$ cfu/g after 12 months of storage, respectively.

The total coliform and *E. coli* were $1.8x10^3$ and $3.9x10^2$ cfu/g for raw prickly pear, respectively. After pasteurization at 85°C/3 min and during frozen storage, the total coliform and *E. coli* were not detected for the two methods A or B. The count of yeasts and molds were $1.06x10^3$ cfu/g. After pasteurization and during storage period, not detected. These results agree with the Egyptian Standard, which limited the microbial load of fruit juices to be free from total coliform, *E. coli* and yeast & molds.

6- Sensory evaluation of prickly pear pulp after storage:

The sensory evaluation of frozen prickly pear pulp showed that the overall acceptability decreased gradually during the storage period. The main decrements were happened in the odor, appearance and mouth feel during frozen storage period.

Part II: Canning of prickly pear nectar:

7- Determination of D-values and Z-values of pectin methylesterase enzyme of prickly pear nectar:

The D-values of pectin methylesterase enzyme of prickly pear nectar was determined to evaluate the thermal process. The D-values of PP nectar at pH 5.0 were 9.55, 4.73, 3.85, 1.85 and 1.08 min at 75, 85, 95, 100 and 110°C, respectively. Z-value of PME enzyme was calculated to be 37.5°C.

8- Evaluation of thermal process of prickly pear nectar:

The thermal process of prickly pear nectar was based on the heat resistance parameters of PME enzyme $D_{100}^{37.5} = 1.85\,\text{min}$. The heating and cooling curves parameters of P.P. nectar were as follows: f_h 8.07 and 4.52 min, and f_c 9.17 and 9.51 min for process at 100.9 (A) and 110.2°C (B), respectively. J_h were 1.19 and 1.28, while j_c were 1.90 and 1.65 for the process (A) and (B), respectively.

Calculation of the F-value (for the processing time of 20 min at 100.9 and 110.2°C after come up times 5.0 and 6.0 min) were 17.41 and 38.33 min, respectively. The numbers of decimal reductions of enzyme equivalent to F-value used for process calculations (F/D) were 9.41 and 20.71 for process A and B, respectively.

The percent of enzyme retention were 3.88×10^{-8} and 1.91×10^{-19} for the process (A) and (B), respectively.

Also, to illustrate the effect of the initial temperature The new calculation of new initial temperature were carried out. For example initial temperatures 28°C and 50°C resulted in

corresponding F-values of 17.42 and 19.13 min, respectively. At the same thermal process temperature of 100.9°C or process at 110.2°C/20 min and initial temperature of 29 and 50°C the calculated F-values were 38.33 and 40.47 min, respectively.

9- Incubation test of canned prickly pear nectar:

After thermal processing, cans were incubated for 10 days at 25°C and for 7 days at 55°C. After incubation period, cans were examined and the results indicated that product was good and Ok for the incubation test.

10- Effect of canning process on some chemical properties of prickly pear nectar:

The total solids and soluble solids of PP nectar were 16.37% and 15.18°Brix increased to 17.04% and 15.95°Brix after preheating. Change after process at 100.9°C/20 min (A) and 110.2°C/20 min (B) were noticeable.

The acidity was 0.089% and it was increased to 0.097% after preheating. After process (A) and (B), while, the pH values were 5.00 and 4.92 for raw and preheated, respectively. After process (A) and (B) the pH values were 4.98 and 4.96, respectively.

Ascorbic acid content (Vit. C) was 3.72 for raw prickly pear nectar. Thermal processing at (A) and (B) resulted in (Vit. C) reduction which became 2.13 and 2.08 mg/100 g, respectively.

Total sugar of raw prickly pear and after preheating were 14.4 and 14.77% and reducing sugar were 3.32 and 3.92%, respectively, while the non-reducing sugar were 11.08 and

10.85%, respectively. After processing A and B, the total sugars were 14.79 and 14.75%, reducing sugars were 4.80 and 4.88% and the non-reducing sugars were 9.99 and 9.87%, respectively.

The color index at 446 nm as O.D. for raw prickly pear nectar was 0.601. Thermal processing at A and B resulted in the color index were 0.505 and 0.460 as O.D. at 476 nm, respectively.

The formol number of raw prickly pear nectar was 6.61 ml NaOH 0.1 N/100 ml nectar. After the process at A and B became 6.33 and 6.26 ml/100 ml, respectively.

The carotenoids content were 0.341 of raw prickly pear nectar and it was reduced after thermal process A and B to 0.241 and 0.210 mg/kg, respectively.

11- Microbiological status of prickly pear nectar:

The total bacterial count (TBC) was $3.60x10^4$, lactic acid bacteria $2.4x10^4$, sporeformer 4.5x10, coliform group $8.7x10^2$ and yeasts and molds $3.7x10^2$ cfu/g of raw prickly pear nectar. After preheating, the counts were reduced to $3.7x10^3$, $2.63x10^3$ and less than 10 cfu/g for TBC, lactic acid bacteria and sporeformer, respectively. Coliform and yeasts and molds were absent after preheating and processing at 100.9°C(A) and 110.2°C(B) for 20 min. On the other hand, the total plate count was reduced to 3.0x10 and 1.3x10 cfu/g after the process(A) and (B), respectively.

12- Sensory evaluation of canned prickly pear nectar:

The sensory evaluation of the canned prickly pear nectar was carried out. The obtained data showed that there were

significant differences between all attributes of raw prickly pear nectar (without process); after process at 100.9 (A) and 110.2°C (B) for 20 min. Also, the results showed that the process (A) had middle score in all attributes and higher than the PP nectar processed (B) which showed the lowest scores in all attributes and the product was not accepted from the panelists after process (B). Same opinions showed that the thermal process (B) was not acceptable.

Part III: Concentrate of prickly pear pulp:

13-Chemical composition of prickly pear juice and concentrate:

The prickly pear pulp was concentrated by two methods (A1 & A2). Method A: [the prickly pear pulp was concentrated in pan under vacuum and heated between 70-80°C to raise the Brix to 22°Brix (A1) and to 31°Brix (A2).

Method (B) (the pulp was centrifuged at 2500 rpm for 15 min to separate the serum and pulp. Serum was concentrated to about 40-45%, then mixed with fresh pulp to obtained PP concentrate of 31°Brix.

Concerning the chemical composition of prickly pear pulp and concentrates A1, A2 and B, the moisture content was reduced from 86.79 to 75.80, 65.64 and 65.40% while the total solids was increased from 13.21 to 24.20, 34.36 and 34.60% for the same sample, respectively.

Also, the pH value was 5.72, 4.87, 4.75 and 4.72, while the titratable acidity were 0.072, 0.175, 0.215 and 0.220% (as citric acid) for the same samples, respectively.

Ascorbic acid content was 13.70, 21.44, 29.31 and 32.90 mg/100 g for prickly pear pulp, concentrate methods A1, A2 and B, respectively.

Total sugars were 10.86, 19.30, 28.82 and 28.70%, the reducing sugars were 10.75, 18.14, 26.64 and 26.78% followed by non-reducing sugars which were 0.11, 1.16, 2.18 and 2.02% for prickly pear pulp, concentration A1, A2 and B, respectively.

The formol number was 24.30 and it was increase to 50.30, 75.72 and 76.67 ml (NaOH 0.1 N/100 g) for concentrates A1, A2 and B, respectively.

The total pectic substances were 0.49, 0.95, 1.54 and 1.92% for the PP pulp, concentrate A1, A2 and B, respectively.

Ash content of these samples were 0.34, 0.68, 0.96 and 0.95%; while crude fiber were 0.38, 0.74, 0.97 and 1.15% for PP pulp, concentration A1, A2 and B, respectively.

Carotenoids content were 0.83, 1.74, 2.28 and 2.41 mg/kg for these prickly pear juices, respectively.

Color index (as O.D. at 476 nm) were 1.902, 2.176, 2.457 and 2.345 for PP pulp concentration, A1, A2 and B, while the degree of discoloration were 16.98, 85.75, 175.4 and 196.9 for PP pulp, A1, A2 and B, respectively.

The refractive index at 20°C was 1.3515 and it was increased to 1.3712, 1.3821 and 1.3809 for concentrates A1, A2 and B, respectively.

14- Sensory evaluation of prickly pear concentration:

The organoleptic results showed that there was no significant difference between the methods of concentration A1, A2, and B in taste, odor, color, mouth feel and overall acceptability. Also, the data showed that the method B had the highest score of the overall acceptability (43.5), while method A2 had the lowest score (40.20) for the same attribute. From obtained data its clear that increasing the degree of Brix in the concentrate was followed by decrease of sensory attributes. On the other hand, method B had the highest score in color and taste attribute.

15- Sensory evaluation for canned prickly pear nectar prepared from concentrated pulp:

The obtained data indicated that no significant differences between canned prickly pear nectar (PPN) prepared from concentrated method A1, A2, B in the taste, color and mouth feel. While, there are significant difference in odor, appearance and overall acceptability. The scores showed no significant difference in all attributes between the method A1 and B after process at 100°C for 20 min.

16- Rheological properties of prickly pear:

Rheological properties of Prickly pear juice and concentrates showed that these are non-Newtonion fluids. It showed pseudoplaastic behavior with presence of thixotropy .

The plastic viscosity η (mPa.S) for prickly pear concentrated by method (B) at temperature of(0.0°C) had the highest value of η, which was (1123 mPa.S). The η value at temperature of (0.0°C) were 178.4, 725.9, 1123, 34.3 and 1.96

mPa.S for prickly pear concentrate (PPC) method A1, A2, B, PP pulp and PP nectar, respectively.

The (τ_0) yield stress values were increased with increasing pulp content and reached 20.90, 22.09, 25.80, 4.56 and 0.34 N/m^2 for the same samples, respectively.

Also, the 10 rpm-viscosity values at temperature (0.0°C) were 1992, 2533, 2966, 457.6 and 30.1 mPa.S for the PP concentrate A1, A2, B, PP pulp and PP nectar, respectively. On the other hand, the power low parameters were calculated. The K values for the same samples at 0.0°C were 14081, 19640, 24458, 5228 and 283.5 mPa.S; respectively.

The (n) flow index values for the PP juice and concentrates were less than 1. That means that the rheological behavior was pseudoplastic. The n-values ranged between 0.10 to 0.45 (dimension less).

The highest value of thixtropy was 207.40 $pa.S^{-1}$ for prickly pear concentrate (method B), While the lowest value of thixtropy was 5.24 $pa.S^{-1}$ for prickly pear nectar.

17- Effect of temperature on flow behavior of prickly pear juice and concentrate:

The obtained data indicate that the activation energy (E_a) was decreased with increasing the total solids of prickly pear concentrate. Activation energy values for concentrates reduced by methods A1, A2, B, PP pulp and PP nectar, were 7952.54, 11655.4, 10207.1, 14078.93 and 16090.08 J/mol ; respectively.

On the other hand, the average values of η_∞ were 3.8463, 2.854, 3.7314, 0.8333 and -3.212 mPa.S for the same samples, respectively.