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Optimization of drying parameters for cactus fruit in hot air tray drier

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Abstract
Cactus fruit (Prickly pear) is popular for its medicinal properties and health benefits. Cactus fruit is used for anti-diabetic effect, anti-cancerous effect, antiviral effect, anti-inflammatory effect, and hypercholesterolemia effect. It is a rich source of minerals like iron, calcium and potassium, vitamins, and antioxidants like betalains. It is necessary to preserve the vitamins, antioxidants, and bioactive compounds of nutritive fruit. Hot air drying is a common method for preserving such fruits with their compounds. Steam blanching is used as a pre-treatment to inactivate enzymes and improve the quality of the final dried product. Proximate, chemical and nutritional compositions were analysed for cactus fruit and mint. Steam blanching treatment was used for inactivation of PME (Pectin-methylesterase) enzyme, which is responsible for the hydrolysis of pectin. Steam blanching was carried out at 96±2 °C for the enzyme inactivation. After blanching, cactus fruits were dried in hot air dryer at three different temperatures (45, 50, 55 °C) till it achieved 7% moisture (w.b.) and drying time for each temperature was recorded. The temperature for drying was selected on the basis of minimum drying time, maximum total betalain content and maximum total antioxidant activity. Cactus fruit contained 30.44±0.1 mg/100 g of total betalain content, 10.25±0.06 mg/100 g of vitamin C, 40.21±0.05 mM/100 g of total antioxidant activity, 1.87 mg/100 g of iron, 563.20 mg/100 g of calcium, 51.80 mg/100 g of phosphorous, 485.80 mg/100 g of potassium and 175.60 mg/100 g of magnesium and 1.11±0.04 % of protein. Hot air drying temperature of 50 °C was optimized based on statistical analysis.

Keywords: Cactus fruit, drying, steam blanching, betalains

Introduction
World is putting more effort to improve the health of the people and their living standards due to increasing poverty and population. People are showing more interest in consuming fruits with antioxidant activity, which provides a vital role in human health. Crops, like cactus pear fruit, which give health and nutritional benefits, have now got increased attention of consumers, diet planners, health advisors, etc. (Feugang *et al*., 2006; Osuna-Martínez *et al*., 2014) [9, 13]. The cactus fruit (*Opuntia* spp.), also known as the Prickly pear, is available in about 200 to 300 species. Cactus fruit is grown mainly in arid and semiarid zones because it is a plant, which needs very low water for growth (Mobhammer *et al*., 2006) [12]. For fruit production, most of the cultivated species are Opuntia ficus-indica, Opuntia xoconostle, and Opuntia megacantba. The fruit of Opuntia Species is juicy, yellow, orange, red or purple colored, and pulpy (Saenz *et al*., 2013) [16].
The cactus fruit is found in different sizes, colors, and shapes. It is elongated in shape and some fruits are in oval shape (Cantwell, 1995) [3]. After harvesting, fruits are graded according to size, maturity, and ripening stage, and damaged fruits are discarded. The largest producer of cactus fruit in the world is Mexico with a 10,000 ha area under cultivation. The largest exporter of cactus fruit to Europe is Sicily. Nowadays, prickly pear is used for new bio-economy by using cladodes and fruit wastage, in Italy people uses cactus pear with some other mixture for biogas production (Singh, 2007; Timpanaro *et al*., 2021) [18, 20].
Generally, the ripe cactus fruit is composed of 33 to 55 percent of the pericarp, 45 to 67 percent of the pulp, and 2 to 10 percent of the seeds. pH value of the fruit ranges from 5.0 to 6.6. Cactus fruit is a good source of betalains and vitamins. This fruit is a good source of vitamin C (ascorbic acid), with a content ranging from 20 to 40 mg/100 g, which is higher than the vitamin C content of grapes, apples, bananas, and pears. Other vitamins like niacin (vitamin B3), riboflavin (vitamin B2), and thiamine (vitamin B1) are also available in fruit. Phenolic compounds are also available in cactus fruit. Flavonoids like quercetin, kaempferol and isorhamnetin give antioxidant effects to fruit. Flavonoids are more efficient antioxidants

than vitamins. The antioxidant activity of cactus fruit is higher than that of other fruits like apples, bananas, berries, tomatoes, and white grapes (Butera *et al*., 2002) [2]. Betalains are the pigment responsible for the red color of the cactus fruit. Betalains are generally used as natural food colorants. Betalains consist of betacyanins and betaxenthins. Betacyanins are responsible for red colour of the fruit and betaxenthins are responsible for yellow colour of the fruit. Essential amino acids like arginine, histidine and conditionally essential amino acid glutamine and some non-essential amino acids like serine and asparagine are also available in cactus fruit. Minerals like iron, phosphorous, calcium, magnesium, and potassium are available in fruit.

Drying is a common method for the purpose of increasing the shelf life of the particular food by removing moisture and hence reducing microbial activity. From ancient time people are using sun drying method for drying of the foods and it is most common method for preserving the food. Conventional drying is done at different temperatures and at different air flow rates resulting into different moisture losses in specific time. More air velocity at high temperature takes less time to reach specific moisture content but sometimes it damages the tissues of the cells. Optimized combination of air flow rate and temperature can give rapid moisture loss without and external damage and give good texture. Drying with combination of blanching as a pretreatment can give great reduction in time to reach at specific moisture content. Drying time also depends on the size of the fruit slices. Fruit slices of smaller size can help in rapid moisture loss than the larger sized fruit slices as reduction of size of slice increases surface area (Ratti, 2001; Doymaz, 2008) [15, 7]. Drying with blanching also helps to inactivate the surface enzymes present in the fruit. Particularly in cactus fruit pectin like substances, namely Polygalacturonase and Pectin methylesterase are present which need to be inactivated.

Keeping in view the nutritional benefits of cactus fruit, to preserve and enhance the cactus fruit storage life without compromising the quality, an attempt has been made in the current research project to optimize the drying condition with the following objectives

1. To evaluate the chemical and nutritional quality of cactus fruit
2. To optimize the steam blanching of cactus fruit slices and drying temperature for drying of cactus fruit slices by using a hot air tray dryer
3. To analyze the effect of drying time and temperature on the nutritional quality of dried cactus fruit slices

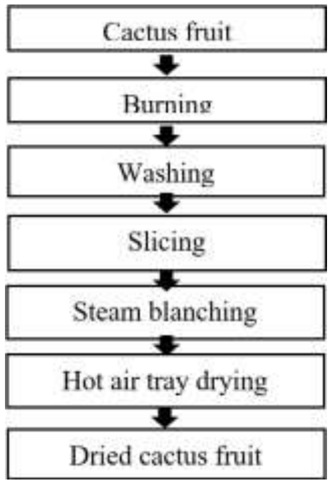
2. Materials and Methods

The entire study was carried out at the College of Food Processing Technology & Bio-Energy, Anand Agricultural University, Anand, Gujarat.

2.1 Materials: Cactus fruits required for conducting the research work were collected from the plant grown at local farms of outskirts of Junagadh city. All the chemicals used for the analysis of the final product and raw product were of analytical grade. All the chemicals were procured from M/s Loba Chemicals, Mumbai, Maharashtra, and M/s Dutt Enterprise, Anand, Gujarat, India. HDPE and polypropylene pouches were used for the packaging of dried cactus fruit slices.

2.2 Methods

2.2.1 Chemical and nutritional attributes analysis: Proximate analysis of cactus fruit was done by using protocols described by AOAC (2019) and Ranganna (2007) [14]. Total sugar (Lane and Eynon method), vitamin C (Dye method (2,6-Dichlorophenol- Indophenol)), acidity was estimated as described by Ranganna (2007)[14]. Antioxidant assay (Spectrophotometer) and minerals (ICP-OES model optima 7000 DV) were estimated.



Flow diagram for drying of cactus slices

2.2.2 Sample preparation: Before blanching, burning was carried out to burn the thorns from skin of cactus fruit. Tien *et al*. (2005) [19] method for burning (Plate 1) was used. The fruits were slowly exposed to gas burner by holding them with S.S. tongs over flame and rolled around the flame so that thorns were all removed from the sides and the top. After burning treatment, the fruits were washed with water. Then, fruits were sliced to 3 mm size with S.S. knife. Sliced fruits were used for further processing.

2.2.3 Blanching of cactus slices: To avoid the leaching of betalains, fresh cactus fruits were blanched using steam at different time. Steam blanching (Plate 2) was carried out at 97±2 °C in water bath (Plate 3) and activity of enzyme was checked at 30 second interval. From the enzyme activity, blanching pre-treatments i.e. time was standardized. The blanched samples were cooled immediately in cold air and sample was checked for enzyme activity (pectin-methylesterase) as per the spectrophotometric method given by Chakraborty *et al*. (2014) [5].

2.2.4 Hot air drying of cactus fruit slices

The experiments were performed in a cabinet type laboratory hot air tray dryer (Plate 4) (make: Navrang Scientific Works Pvt. Ltd., New Delhi) and fitted with a manually controlled digital thermostat, PT – 100 thermocouple, a blower driven by 0.5 hp motor and electric finned heaters of 3×1 kW. The tray dryer was adjusted to the selected temperature (45, 50, and 55 °C) and air velocity of 1 m/s for about half an hour before the starting of experiment starts to achieve the steady state condition. The moisture loss from the sample was recorded at every 15 min time interval in the beginning and later after every 1 h time interval during drying. The drying process was stopped when the moisture content of cactus fruit slices reached to about 7 (%w.b.) and total drying times for each temperature were recorded. All the experiments were conducted in triplicate for selected temperatures and each differently treated sample. Dried cactus fruit slices were analyzed for total antioxidant activity and total betalain content using the methods described in chemical and nutritional analysis respectively. Both analyses were done in triplicates.

Plate 1: Burning

Plate 2: Steam blanching

Plate 3: Water bath

Plate 4: Hot air tray dryer

2.2.5 Statistical analysis: For standardization of drying temperature for drying of cactus fruit slices, the numerical optimization technique of the software Design Expert Version 12 was used.

3. Results and Discussion

3.1 Evaluation of chemical and nutritional quality of cactus fruit:

Analysis of proximate composition such as moisture, protein, fat, fiber, ash, and carbohydrate along with various chemical properties such as acidity, total sugar, and nutritional properties such as vitamin C, total antioxidant activity, total betalain content as well as mineral profile of cactus fruit was determined as per the method described in the methodology. The data obtained for the proximate composition, chemical analysis, nutritional composition and mineral profile of cactus fruit is presented in Table 1.

Proximate analysis is important for determining the compositional status of any sample as it helps in further product development work. For raw cactus fruit, the values of moisture, protein, fat, crude fiber, ash, and carbohydrate were found to be in the range of 84.28±0.06, 1.11±0.04, 0.32±0.02, 1.2±0.02, 0.631±0.05 and 12.49±0.04, respectively (Table 1). The reported values were generally in consonance with the values reported by Sawaya *et al*. (1983) [17]; Chiteva & Wairagu (2013) [6].

Table 1: Proximate, chemical, nutritional and mineral analysis of cactus fruit

Parameters	Cactus fruit	Parameters	Cactus fruit
Moisture (%)	84.28±0.06	Iron (mg/100 g)	1.87
Protein (%)	1.11±0.04	Calcium (mg/100 g)	563.20
Fat (%)	0.32±0.02	Magnesium (mg/100 g)	175.60
Crude fibre (%)	1.2±0.02	Phosphorous (mg/100 g)	51.80
Ash (%)	0.631±0.05	Potassium (mg/100 g)	485.80
Carbohydrates (%) (by difference)	12.49±0.04	Sodium (mg/100 g)	8.83
Total sugar (g/100 g)	1.25±0.07	Total antioxidant activity (mM/100 g)	40.21±0.05
Acidity (%)	0.32±0.002	Total Betalain content (mg/100 g)	30.44±0.1
Vitamin C (mg/100 g)	10.25±0.06		

Note: All values are mean±standard deviation

The protein, fat, crude fiber, and ash content of cactus fruit were found to be slightly higher which might be due to the whole fruit being taken for the proximate analysis. For cactus fruit, the value of total sugar, acidity, vitamin C, total antioxidant activity, and total betalain content were found to be in the range of 1.25±0.07 g/100 g, 0.32±0.002 %, 10.25±0.06 mg/100 g, 40.214±0.05 mM/100 g and 30.44±0.1 mg/100 g, respectively (Table 1). It can be seen that Cactus fruit showed high antioxidant activity and was a rich source of vitamin C. The reported values were in accordance with the values reported by Elbana *et al*. (2020) [8]. Betalain is a natural pigment present in cactus fruit pulp and is also found in the peel. The present study showed that the total betalain containing cactus fruit was 30.44±0.1 mg/100 g, which is higher than other varieties, i.e. *Opuntia ficus* Indica.

The Inductive Couple Plasma-Optical Emission Spectrometry, ICP-OES results (Table 1) showed that raw cactus fruit is a good source of minerals. Among all minerals present in cactus fruit, calcium showed the highest value of 563.20 mg/100 g, followed by potassium (485.80 mg/100 g), magnesium (175.60 mg/100 g), phosphorous (51.80 mg/100 g), sodium (8.83 mg/100 g) and iron (1.87 mg/100 g). The reported values of the mineral composition of cactus fruit were in accordance with values reported by Cha *et al*. (2013) [4] and Kizil *et al*. (2010) [11].

3.2 Optimization of process parameters for blanching and hot air drying of cactus fruit slices

3.2.1 Optimization of steam blanching for cactus fruit slices

Steam blanching was carried out to help in boosting the drying process and to assist in maintaining the final quality of cactus fruit slices. It helps to inactivate the enzyme, i.e. PME (pectin-methylesterase), which is responsible for the breakdown of the pectin structure. Steam blanching was carried out at a constant temperature (96±2 °C) for different time intervals (30, 60, 90, 120, and 150 seconds) and the result is observed that PME enzyme inactivated after 150 seconds of steam blanching treatment. After blanching, it was observed that the slices of cactus fruit became softer.

3.2.2 Optimization of drying temperature for drying of cactus fruit slices

Drying of cactus fruit slices was carried out in hot air tray dryer at different temperatures (45, 50, and 55 °C) with optimized steam blanching treatment. Dried cactus fruit slices were analyzed for drying time, total betalain content, and total antioxidant activity. Optimization of drying temperature was carried out on the basis of higher retention of total betalain content, total antioxidant activity, and lowest drying time. The data obtained from drying were depicted in fig.1

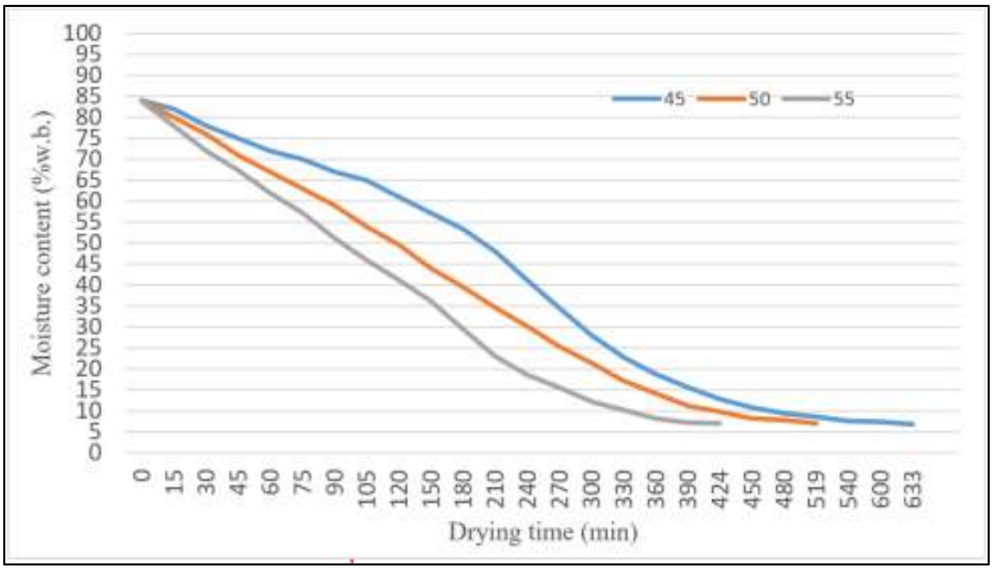


Fig 1: Drying curve for drying of cactus fruit slices by hot air tray drying at 45, 50 and 55 °C

In the above fig. 1, maximum drying time (661 min) was observed in control sample dried at 45 °C, followed by 633 min was observed for the blanched sample dried at 45 °C. Lowest drying time (424 min) was observed in blanched sample dried at 55 °C, followed by 442 min was observed for control sample dried at 55 °C. It revealed that drying temperature and blanching have significant effect on drying time. As the temperature increases, total drying time required for drying decreases also at the same drying conditions, blanched samples dried faster followed by control samples.

3.3 Effect of drying time and temperature on the quality of dried cactus fruit slices

3.3.1 Effect of drying temperature on the drying time of cactus fruit slices

A minimum drying time of 424 min for the drying of cactus fruit slices was found at a drying temperature of 55 °C, followed by 519 min at 50 °C and a maximum drying time of 633 min at 45 °C. Drying temperature showed a clear effect on drying time, as the temperature increased, the total drying time required for drying decreased shown in fig. 2. The same drying time trend for hot air drying was reported by Andreu *et al*. (2018) [1]. The goal of drying time for experimental design was kept at a minimum.

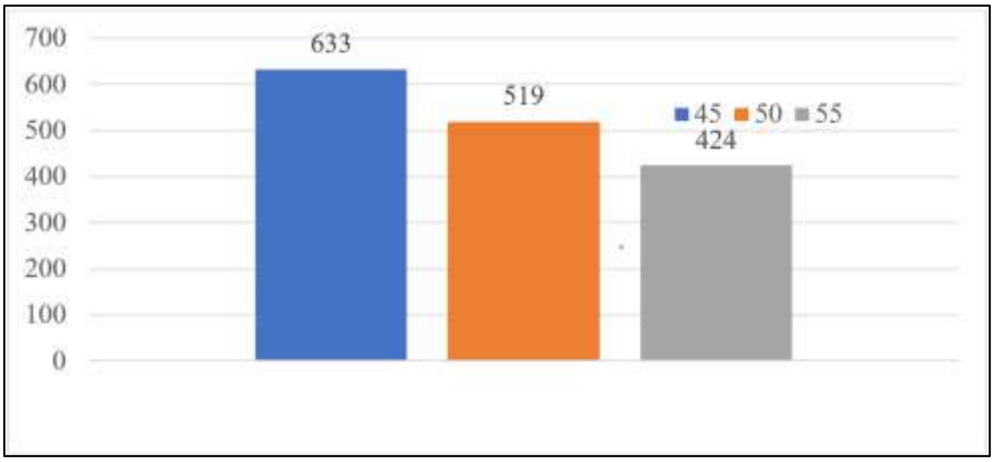


Fig 2: Effect of drying temperature on drying time of cactus fruit slices

3.3.2 Effect of drying temperature on total betalain content of cactus fruit slices

From Fig. 3, maximum total betalain content of 25.107 mg/100 g was found at drying temperature of 45 °C, followed by total betalain content of 24.486 mg/100 g at 50 °C and lowest total betalain content was found at drying temperature of 55 °C. Total betalain content was decreased as the drying temperature increased. It was observed that drying temperature was inversely related with the retention of total betalain content. Same total betalain content trend for hot air drying was reported by Gokhale and Lele (2014) [10]. The goal of total betalain content for experimental design was kept as maximum.

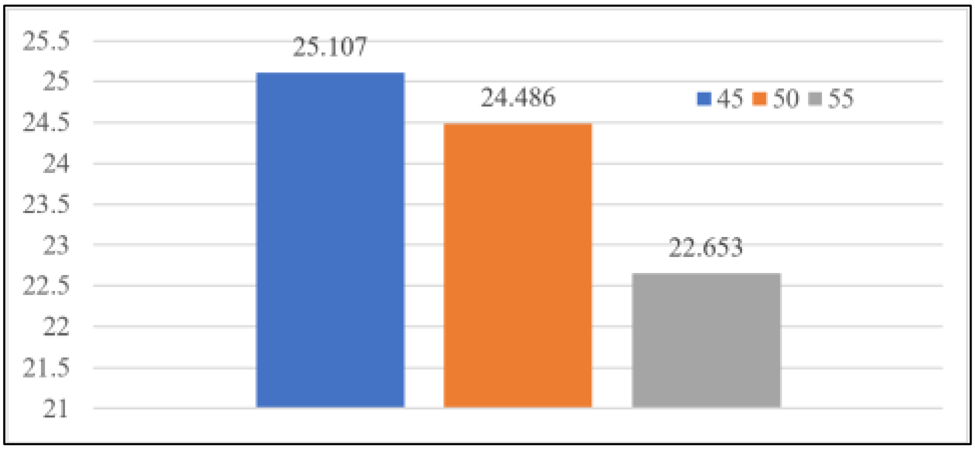


Fig 3: Effect of drying temperature on total betalain content of cactus fruit slices

3.3.3 Effect of drying temperature on total antioxidant activity of cactus fruit slices

From, Fig. 4, the maximum total antioxidant activity of 45.278 mM/g was found at a drying temperature of 55 °C, followed by 43.393 at 50 °C, and the lowest total antioxidant activity was found at a drying temperature of 45 °C. Total antioxidant activity was increased as the drying temperature increased. Drying temperature showed a direct relationship with the retention of antioxidant activity. Total antioxidant activity increased as the drying temperature increased, as betacyanins are less heat stable. With the increase in temperature, betacyanins started to degrade and it produced some phenols that actually acted as antioxidants (Gokhale and Lele, 2014) [10]. The goal of total antioxidant activity for experimental design was kept at a maximum.

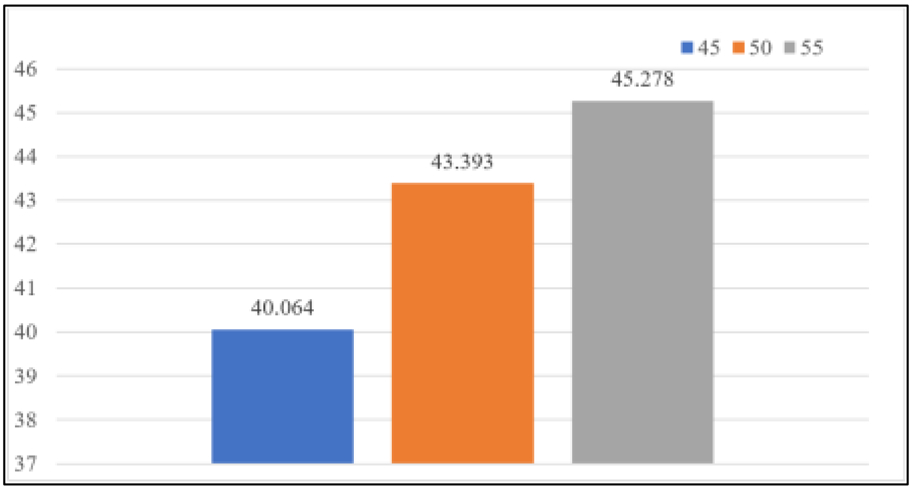


Fig 4: Effect of drying temperature on total antioxidant activity of cactus fruit slices

4. Standardization of drying temperature for cactus fruit slices

For standardization of drying temperature for drying of cactus fruit slices, the numerical optimization technique of the software Design Expert Version 12 was used. During the standardization process, specific constraints were applied on the variables in the software as shown in Table 2.

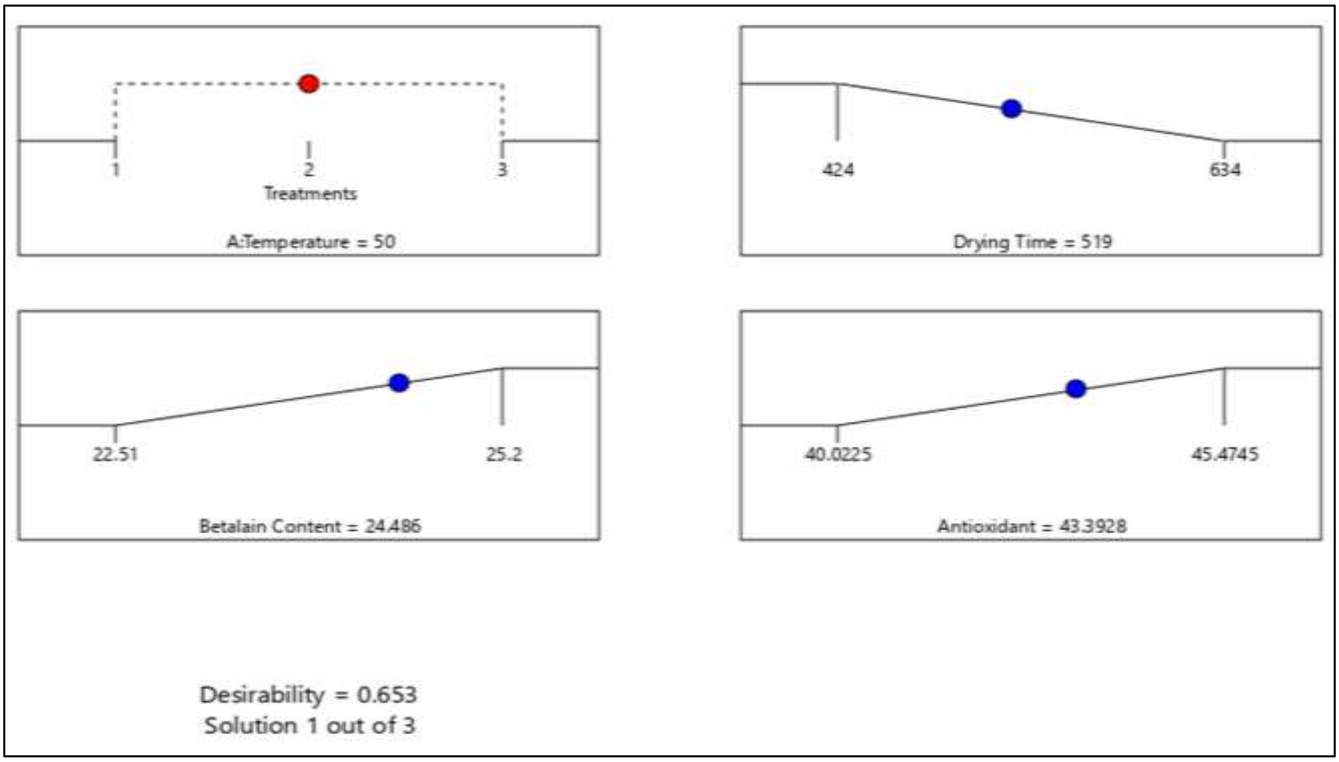


Fig 5: Effect of drying temperature on total antioxidant activity of cactus fruit slices

Table 2: Constraints during the optimizations of drying temperature for drying of cactus fruit slices in Design expert software

Name	Goal	Lower limit	Upper limit	Lower weight	Upper weight
Temperature	is in range	45	55	1	1
Drying time	minimize	424	634	1	1
Total Betalain content	maximize	22.51	25.2	1	1
Total Antioxidant activity	maximize	40.0225	45.4745	1	1

Single factor design was used in which temperature was used as a factor, different drying temperature as a level. So, total 3 solutions were found by software and out of which one optimum solutions showing the optimum condition of independent variables with highest desirability were selected. The best solution for drying temperature was found to be 50 °C with desirability value of 0.752 (Fig. 5). Under optimized condition, for drying of cactus fruit slices, the value of drying time was predicted as 519 min, total betalain content as 24.486 and total antioxidant activity as 43.393.

4. Conclusions

The present research resulted in the optimization of drying of cactus fruit with high amount of antioxidants. Steam blanching of cactus fruit slices for 150 secs, inactivated pectin methylesterase (PME) enzyme, and resulted to soften slice. Raw cactus fruit was observed to be rich source of vitamin C, calcium, potassium, iron, antioxidant activity, total betalains and total sugar. Statistically, hot air tray drying at 50 °C, drying time was found lower than the drying at 45 °C, Total betalain content was found higher than the drying at 55 °C, Total antioxidant activity was found higher than the drying at 45 °C.

5. References

1. Andreu L, Nuncio-Jáuregui N, Carbonell-Barrachina ÁA, Legua P, Hernández F. Antioxidant properties and chemical characterization of Spanish *Opuntia ficus-indica* Mill. cladodes and fruits. Journal of the Science of Food and Agriculture. 2018;98(4):1566-1573.
2. Butera D, Tesoriere L, Di Gaudio F, Bongiorno A, Allegra M, Pintaudi AM, *et al*. Antioxidant activities of Sicilian prickly pear (*Opuntia ficus indica*) fruit extracts and reducing properties of its betalains: betanin and indicaxanthin. Journal of agricultural and food chemistry. 2002;50(23):6895-6901.
3. Cantwell M. Post-harvest management of fruits and vegetable stems. FAO Plant Production and Protection Paper (FAO); c1995. p. 132.
4. Cha MN, Jun HI, Lee WJ, Kim MJ, Kim MK, Kim YS. Chemical composition and antioxidant activity of Korean cactus (*Opuntia humifusa*) fruit. Food science and biotechnology. 2013;22:523-529.
5. Chakraborty S, Rao PS, Mishra HN. Effect of pH on enzyme inactivation kinetics in high-pressure processed pineapple (*Ananas comosus* L.) puree using response surface methodology. Food and Bioprocess Technology. 2014;7:3629-645.
6. Chiteva R, Wairagu N. Chemical and nutritional content of *Opuntia ficus-indica* (L.). African Journal of Biotechnology. 2013;12(21):3309-3312.
7. Doymaz I. Convective drying kinetics of strawberry. Chemical Engineering and Processing: Process Intensification. 2008;47(5):914-919.
8. Elbana M, Elwakeel M, Rashad M. On-Farm Water Management and its Impacts on Productivity and Quality of Cactus Pear (*Opuntia ficus indica*). Alexandria Science Exchange Journal. 2020;41:513-522.
9. Feugang JM, Konarski P, Zou D, Stintzing FC, Zou C. Nutritional and medicinal use of Cactus pear (*Opuntia* spp.) cladodes and fruits. Frontiers in Bioscience-Landmark. 2006;11(3):2574-2589.
10. Gokhale SV, Lele SS. Betalain content and antioxidant activity of *Beta vulgaris*: Effect of hot air convective drying and storage. Journal of Food Processing and Preservation. 2014;38(1):585-590.
11. Kizil S, Hasimi N, Tolan V, Kilinc E, Yuksel U. Mineral content, essential oil components and biological activity of two mentha species. Turkish Journal of Field Crops. 2010;15(2):148-153.
12. Mobhammer MR, Stintzing FC, Carle R. Cactus pear fruits (*Opuntia* spp.): A review of processing technologies and current uses. Journal of the Professional Association for Cactus Development. 2006;8:1-25.
13. Osuna-Martínez U, Reyes-Esparza J, Rodríguez-Fragoso L. Cactus (*Opuntia ficus* Indica): A Review on its Antioxidants Properties and Potential Pharmacological Use in Chronic Diseases. Natural Products Chemistry & Research. 2014;2:153.
14. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Education; c1986.
15. Ratti C. Hot air and freeze-drying of high-value foods: a review. Journal of food engineering. 2001;49(4):311-319.
16. Saenz C, Berger H, Rodríguez-Félix A, Galleti L, Corrales García J, Sepúlveda E. Agro-industrial utilization of cactus pear. Food and Agriculture Organization, Rome; c2013.
17. Sawaya WN, Khatchadourian HA, Safi WM, Al-Muhammad HM. Chemical characterization of prickly pear pulp, *Opuntia ficus-indica*, and the manufacturing of prickly pear jam. International Journal of Food Science & Technology. 1983;18(2):183-193.
18. Singh G. Opportunities for promotion of cactus (*Opuntia* spp.) as livelihood source in rainfed areas. Technical Bulletin No. 1/2007, Central Soil Salinity Research Institute, Karnal, (India); c2007. p. 23.
19. Tien DV, Beynen AC. Growth performance of lambs in Phangrang, Vietnam: effects of a dietary supplement containing prickly-pear cactus. Tropical animal health and production. 2005;37:237-244.
20. Timpanaro G, Cosentino S, Danzì C, Foti VT, Testa G. Prickly pear for biogas production: technical-economic validation of a biogas power installation in an area with a high prevalence of cacti in Italy. Biofuels, Bioproducts, and Biorefining. 2021;15(3):615-636.