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Physicochemical properties of wild grown prickly pear fruits (*Opuntia ficus-indica*) in Yemen

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Abstract. This study aimed to estimate the physical and chemical properties of prickly pear fruits. Prickly pear fruit samples were collected from local markets in Dhamar, Yemen. The results showed that the mean weight of prickly pear fruits was 89.27 g, while the pulp, peel, seeds, and extracted juice weights were 47.57, 40.96, 3.52, and 37.07 g, respectively. The weight percentages of pulp, peel, seeds, and extracted juice were 53.72, 45.38, 3.79, and 34.85% of the fruit's weight, respectively. The chemical properties of prickly pear juice were: 86.83% moisture, 12.75 ˚brix total soluble solids, 13.17% total solids, 11.78% total sugars, 7.86% reducing sugar, 3.90% non-reducing sugar, 6.07 pH, 0.09% total acidity, and 28.41 mg/100 mL ascorbic acid content. The ˚brix/acidity ratio in prickly pear pulp extract was 178.87. These findings indicated that the prickly pear fruits that grow wild in Yemen possessed the majority of the desirable physicochemical properties, such as high soluble solids, low acidity, and a low seed content percentage, which make them marketable and exportable.

Keywords: *Cactus pear, local market, sugar, marketable, and exportable*

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1. Introduction

The prickly pear (*Opuntia* spp.) spreads in many countries, such as Mexico, the American hemisphere, Africa, and Mediterranean Basin countries. Prickly pear belongs to the Cactaceae family, Opuntioideae subfamily, and *Opuntia* genus, which is characterized by its flat, structured leaf and stem. The genus *Opuntia* includes about 150–180 species (Anderson, 2001). *Opuntia ficus-indica* (L.) is the most famous of the prickly pear species that produce edible fruits (Yahia & Sáenz, 2011). The prickly pear fruit has the potential to provide food, beverages, and acceptable levels of nutrients, in addition to significant pharmacological potential and promising active ingredients in human nutrition and health. It is a good source of some nutrients like minerals (Ca, Mg, K, and P), amino acids (alanine, arginine, and asparagine), and vitamins (vitamins C, E, K, and β-carotenes) and has antioxidant properties (Cota-Sánchez, 2016; Osuna-Martínez et al., 2014). Medical and nutritional benefits of prickly pear fruits have been recognized for many centuries, as they contain many active biological nutrients and antioxidants. Dehbi et al. (2013) reported that prickly pear fruits taste sweet and good because they have a lot of sugar and not much acid.

The prickly pear fruit fraction percentage varied according to the cultivar type. Gurrieri et al. (2000) reported that the difference in the fruits' pulp weight percentage is related to the variation in the fruits' size and thickness of the prickly pear fruit peel. Karababa et al. (2004) reported that the weight of both fruit and pulp was positively affected by an increase in seed content. The weight of whole fruit, peel, pulp, and seeds varied depending on the stage of maturity and cultivar type. The weight of fruit pulp increases while the weight percentage of both the peel and seeds decreases with the advance in maturity of the fruits, and the individual fruit weight at different stages of ripeness was widely varied. The chemical composition of prickly pear fruit and its physicochemical properties vary greatly during the ripening stage. El-Gharras et al. (2006) found that as prickly pear fruits got riper, their pH and sugar content went up while their acidity and moisture content went down.

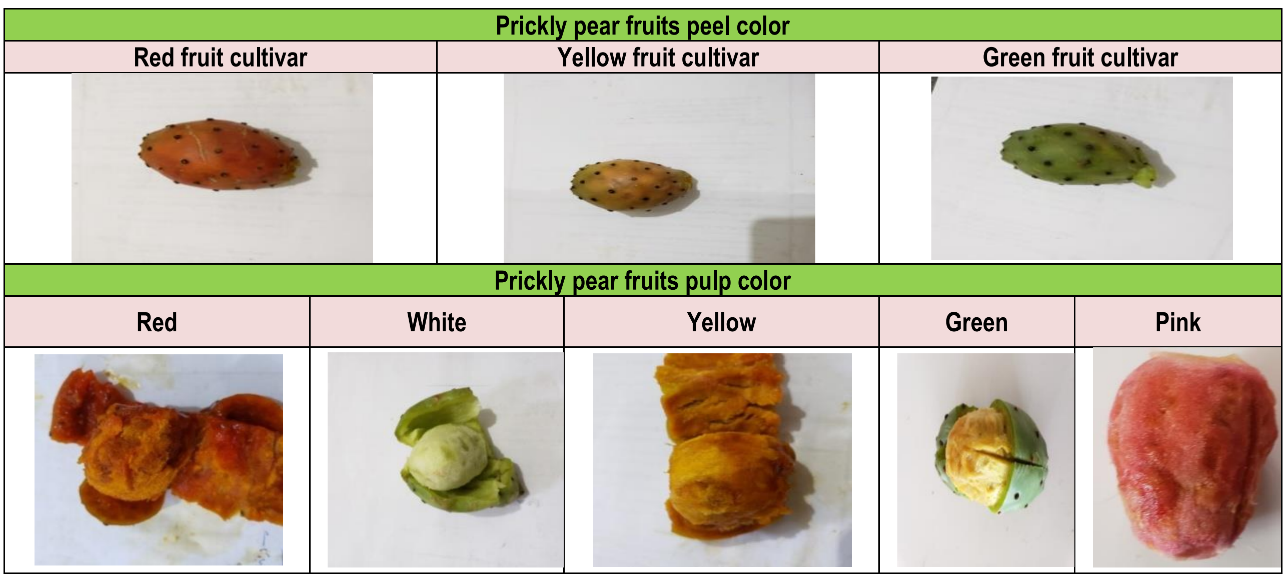
Patil and Dagadkhair (2019) found that prickly pear fruits had the following chemical structure: moisture (83–95%), protein (0.2–1.6%), fat (0.09–1.7%), ash (0.3–0.51%), total sugar (8–17%), total soluble solids (11.5–17%), titratable acidity (0.10–0.25%), and pH value (5.0–7.1). El-Samahy et al. (2006) reported that the yellow prickly pear pulp from Egypt had low acidity and high pH values. Abou-Zaid et al. (2022) reported that the red prickly pear juice had higher levels of TSS, polyphenols, flavonoids, and betalains, while the yellow prickly pear had higher levels of pH and carotenoids. Prickly pear fruits are classified into four weight classes in Italy: extra-large fruits (>160 g), first class (120–160 g), second class (80–120 g), and third class (80 g) (Barbera et al., 1992).

The cactus pear plants are naturalized and grow in brushy areas in some regions of Yemen. So far, no attempts at breeding studies or commercialization practices have been documented; the cactus pear is still a wild species in this country. In the last few years, only some commercial plantations of prickly pear were established around Sana'a governorate. The goal of this study is to figure out some of the physical and chemical properties of prickly pear fruits that grow wild in Yemen and are sold in the city of Dhamar.

2. Materials and Methods

2.1. Sample collection

Yellow, red, purple, and white pulp-colored prickly pear fruits were included in this study (picture 1). These fruits originated in areas near Dhamar city, where they grow naturally in the mountains (picture 2). Prickly pear fruits were collected from local markets in Dhamar city. The fruits were randomly selected from the markets. The fruits were placed in plastic bags and transferred to the laboratory of the Biotechnology and Food Technology Department, Faculty of Agriculture and Veterinary Medicine, Thamar University, where physical and chemical analysis was carried out. The result of any parameter was calculated as the mean value for different pulp color prickly pear fruits samples.



Picture 1. Prickly pear fruits' peel and pulp color from Dhamar city markets, Yemen

2.2. Physical properties

The total weight of fruit was measured, and then the peel was removed from the fruits. After fruits peeling, pulp and peel weight was measured. After weighing pulp, the pulp was crushed and pressed through cloth pieces and the seeds were separated from pulp through sieving and the weight of seeds and juice was measured by digital balance. The juice percentage was calculated by dividing the juice weight over the whole fruit weight.

			
Prickly pear plant	**Fruits**	**Pulp**	**Seeds**

Picture 2. The prickly pear plant, fruits, pulp, and seeds grow wild in Yemen

2.3. Chemical properties

Prickly pear juice was obtained from fruit pulp. Fruit pulp was blended, sieved to remove the seeds, and then the extracted juice was used for chemical analysis, which included moisture content, acidity, total solids and total soluble solids (TSS), total sugar, reducing and non-reducing sugar, ascorbic acid, and pH values as follows:

2.3.1. Moisture and total solids content

A microwave oven drying method was used to determine the moisture and total solids content of fruit juice. Three replicates were analyzed, and the average was calculated.

2.3.2. Total soluble solids (TSS)

The total soluble solids (˚brix) of prickly pear fruit juice were determined using a manual refractometer from the Atago Company, Japan.

2.3.3. Sugar content

The content of direct-reducing sugar was measured by the Lane-Eynon method. 20 mL of the sample juice was transferred to a 500 mL volumetric flask. To the phenolphthalein end point, 100 mL of water was added, followed by neutralization with NaOH solution. A 10 mL solution of neutral lead acetate was added, shaken, and allowed to stand for 10 minutes. A potassium oxalate solution was added in small amounts until there was no further precipitation. The volume was completed with distilled water, mixed well, and filtered through Whatman No. 1 filter paper. 50 mL of filtrate was transferred to the burette. 5 mL each of Fehling A and B solutions were transferred to a 250 mL conical flask. The sample solution was added with continuous heating of the flask to boiling, and 3 drops of methylene blue indicator were added. This completed the titration until the indicator was decolorized and the brick red color was presented. The consumed sample solution in titration was recorded. A duplicate titration was performed, and the sample solution average was calculated. The equation was used to calculate the direct reducing sugar. The Fehling factor was primarily found by using known glucose solution concentrations.

$$\text{Direct reducing sugar (\%)} = \frac{\text{(Fehling factor) x vol.made up x 100}}{\text{Wt.of sample x 1000}}$$

For total reducing sugar, 50 mL of the clarified, de-leaded filtrate sample was transferred to a 100 mL volumetric flask. 5 mL of concentrated HCl was added and allowed to stand at room temperature for 24 hours. The solution was neutralized with a concentrated NaOH solution followed by 0.1N NaOH using phenolphthalein as an endpoint indicator. The volume was made with distilled water. 50 mL of the sample solution was transferred to the burette. Titration against Fehling's solution, similar to the procedure described for reducing sugar, was performed. The total sugar, as invert sugar, was calculated.

$$\text{Total reducing sugar (\%)} = \frac{\text{mg. of invert sugar (Fehling factor) x final vol. made up x original volume x 100}}{\text{Wt. of sample (mg)} \times \text{aliquot taken for inversion} \times 100}$$

Non-reducing sugar was calculated by subtracting the direct reducing sugar from the total reducing sugar and multiplying by the 0.95 factor. Total sugar was calculated as the sum of reducing and non-reducing sugar.

2.3.4. pH value

The pH value in the fruit juice was estimated using a pH meter from Hanna Company. The pH meter electrode was immersed directly in the juice extracted from prickly pear pulp.

2.3.5. Titratable acidity

Using the titration method with sodium hydroxide NaOH (0.1 N) and phenolphthalein indicator, the acidity of prickly pear fruit juice was measured. The amount of alkali consumed in titration was recorded, and the acidity was calculated as g of citric acid per 100 g of juice.

2.3.6. Ascorbic acid content

Ascorbic acid was estimated by the iodine titration method according to Ciancaglinia et al. (2001). 20 mL of the prickly pear juice was transferred to a 250 mL Erlenmeyer flask, and 25 mL of distilled water was added. 10 mL of the diluted sample was transferred to a 250 mL beaker, and 1 mL of cooled, filtered starch was added. Titration with iodine solution was performed at a slow rate to the end point, which was dark blue in color. The volume of iodine solution used in titration was recorded, and the ascorbic acid content was calculated as follows:

$$\textbf{Ascorbic acid (mol/L)} = \frac{\textbf{mL of Iodine} \times \textbf{M of Iodine}}{\textbf{Sample volume (mL)}}$$

The amount of ascorbic acid in (mg/100 mL) was calculated using the following equation:

Ascorbic acid (mg/100mL) = Ascorbic acid (mol/L) x (M.W) of Ascorbic acid x 100.

2.4. Statistical analysis

The data were subjected to descriptive statistical analysis to calculate the mean and the standard deviation for each studied parameter using the SPSS program (version 16).

3. Results and Discussion

3.1. Physical properties

3.1.1. Weight of fruit and its fractions

The weight of prickly pear fruits and its different fractions are important parameters for fruits destined for export as well as quality parameters that affect consumer acceptance. In prickly pear fruits that are destined for export, the weight of the whole fruit and its pulp must exceed 120 and 55–60 g, respectively (Inglese et al., 1995). This criterion guarantees that the exported prickly pear fruits are of good quality and have reached a suitable level of ripeness, while also ensuring they are free from any damage. The results in Table 1 show the mean value of weight for fruits and their different fractions. The average fruit's weight was 89.27 g. The pulp, peel, seeds, and juice weights were 47.57, 40.95, 3.52, and 37.07 g, respectively. The findings regarding weight of fruits in the present study are consistent with the findings of El-Gharras et al. (2006) in Moroccan prickly pear fruits, which were 75.13, 89.98, and 117.17 g in green, half-ripe, and ripe fruits, respectively. It appears that the juice content of prickly pear fruit is dependent on the maturity of fruit, as well as the parts, season and region in which it was grown. These findings are consistent with the findings of El Finti et al. (2013), who found that the weight of prickly pear fruits ranged between 81.5 and 107.5 g and the fruit pulp weight ranged between 47.98 and 63.44% in different varieties of prickly pear fruits. These show that the fruit pulp weight is directly related to the weight of the entire fruit. It was also within the range of the results obtained by Karababa et al. (2004) in prickly pear fruits from Turkey's southeastern coast, where the fruits' weight (76.7–102), core (40.5–55.1), and pulp (35.5–50.9) were measured. The weights of the fruit's core and pulp were strongly linked, which suggests that they are closely related. Moreover, Gómez-Maqueo et al. (2020) reported the results for prickly pear fruit weight from the Canary Islands, which was 78.9–129.6 g. The findings from this study are consistent with the findings of previous studies, indicating that the weight of prickly pear fruits is highly variable, ranging from 75.13 to 129.6 g in different varieties and locations.

Table 1. The weight of prickly pear fruit and its different fractions (g)

Parameter	Mean	SD
Whole fruit	89.27	19.14
Fruit pulp	47.57	8.99
Fruit peel	40.95	12.12
Fruit seeds	3.52	2.80
Fruit juice	37.07	11.63

Note. The values are the mean ± standard deviation (SD) measurements (n = 25).

Koalaga et al. (2019) reported that the fruits, pulp, peel, and seeds weight for prickly pear varieties in Northern Morocco ranged from 78.43–96.70, 52.75–64.74, 28.34–32.77, and 2.58–3.4 g, respectively. These results are higher than those found by Roghelia & Panchal (2016), who found that the prickly pear fruit weight was 24.15 g and the pulp weight was 21.07 g. And also higher than the results of Boudjouan et al. (2022), who found that the prickly pear fruit's weight was 65.62 g. But they are less than those found by El-Samahy et al. (2006) in prickly pear fruits from Ismailia, Qalyubia, and Sharkia governorates, Egypt, which were 110.19, 120.57, and 133.50 g, respectively. The minimum weight for prickly pear fruits must be 90 g (Codex, 1993). The results obtained in this study for fruit weight are near this minimum value. It could be because the fruit samples included were wild-grown and un-irrigated, as well as the low rainfall rate during this study in the regions where the prickly pear plants grow. Nunes et al. (2017) reported that the weight of fruits that originated from high annual rainfall regions is higher than fruits from the lowest annual rainfall regions. When they were ready to be picked, the fruit and pulp of prickly pear plants that were given extra water or water from a business were bigger (Zegbe, 2020).These findings suggest that the low weight of fruits found in this study is likely due to environmental conditions, including limited water availability and wild growth, which have a significant effect on the production of prickly pear fruits.

3.1.2. Weight percentage of fruit fractions

The results in Table 2 show that the pulp weight percentage was 53.72, while the peel and seed weight percentages were 45.38 and 3.79, respectively. These results are in agreement with those mentioned by Dehbi et al. (2013), and they reported that the prickly pear pulp weight in Morocco was 50.62–62.78% of fruit weight. They are within the range of the results of Kumar et al. (2018), who reported that the percent of peels, pulp, and seeds in prickly pear fruits was 33–55, 45–67, and 2–10 of the fruit weight, respectively, and they fell in the range of Patil and Dagadkhai (2019). Our results are in agreement with these findings, as the percent of prickly pear pulp we found (53.72%) is between 50.62 and 62.78 of fruit weight. They found the pulp, peel, and seed weight percentages to be 39–67, 33–55, and 2–10 of the prickly pear fruit's weight, respectively. It is also in the range of the results of peel, pulp, and seed weight percentages for prickly pear fruits from the Canary Islands found by Gómez-Maqueo et al. (2020), which were 41.3–55.7, 38.2–51.8, and 3.5–6.9, respectively. It is similar to the results of Koalaga et al. (2019), who reported that the seed weight percentage for prickly pear varieties in Northern Morocco ranged from 3.08–3.61. Overall, the results of these studies indicate that there is significant variation in the percentages of peel, pulp, and seeds in prickly pear fruits across different locations.

Table 2. The weight percentage of prickly pear fruit different fractions parts

Parameter	Mean	SD
Pulp	53.72	5.25
Peels	45.38	5.58
Seeds	3.79	3.63
Juice	34.85	4.64
Seeds/pulp	0.08	0.07

Note. The values are the mean ± standard deviation (SD) measurements (n = 25).

The results in Table 2 also showed that the juice weight percentage was 34.85 in the prickly pear fruits. This result was less than the results of Abdulkadir et al. (2022), who found the juice percentage was 54.18 and 49.41 in red and white prickly pear fruit juice, respectively. For the agro-industrial sector, the high levels of prickly pear fruit juice increase their commercial value because the juice content is the first factor that influences the cost price (Bourhia et al., 2020). These results suggest that further investigation is necessary to understand the variables that influence the juice content of prickly pear fruit juice as well as its commercial value. The presence of seeds in prickly pear fruits is a major deterrent to first time consumers, so fruits with fewer, smaller, and softer seeds are more acceptable (Caplan, 1995). The seed-to-pulp weight ratio in prickly pear fruits was 0.077. These results are lower than El Finti et al. (2013) results, which were 0.11–0.24 for different varieties of Moroccan prickly pear fruits. The presence of small, soft and fewer seeds in Yemeni prickly pear fruits is indicative of their good quality and consumer acceptability.

3.2. Chemical properties

3.2.1. Moisture and total solids content

Table 3 shows what chemicals are in the juice of prickly pear fruit pulp. The moisture content of the juice of prickly pear fruit pulp was 86.83%. This finding is consistent with the finding of Askar and El Samahy (1981) that the moisture content in prickly pear pulp was 85.1% and with the results of Boudjouan et al. (2022), who found the moisture content in prickly pear fruit to be 86.48%. It is similar to the results of Mohammed et al. (2014) and Roghelia & Panchal (2016), which were 84.55 and 84.78–87.25%, respectively. The findings of this study regarding the moisture content of the juice of prickly pear fruit pulp support previous findings from other researchers. These results are lower than the results of Dehbi et al. (2014). They found that the moisture content of Moroccan yellow prickly pear pulp was 98.81%. These findings demonstrate that the moisture content of prickly pear fruit can vary widely, depending on the variety, climatic factors, and ripeness.

According to Table 3, the total solids content of prickly pear fruit pulp juice was 13.17%. These results are similar to the results of El-Samahy et al. (2009) and Bareh et al. (2012). They reported that the total solids content of Egyptian prickly pear juice was 12.9–13.5%. It is also closer to the 13.8–17.9% range reported by Reis et al. (2018). So, the results in Table 3 show that the total solids content of prickly pear fruit pulp juice is similar to what has been found in other studies and is within the range of what is usually found in Egyptian prickly pear juice. A lower value of total solids was reported by Jambi (2017) in prickly pear fruit from Saudi Arabia, which was 10.63%. El-Samahy et al. (2006) reported that the total solids in yellow prickly pear pulp from Ismailia, Qalyubia, and Sharkia governorates, Egypt, were 11.82%, 11.68%, and 13.73%, respectively. This lower value can be attributed to the type of fruit used and the region where it was grown. Total solids and total soluble solids tend to be highest in the fruits of prickly pear plants that were not watered (Zegbe, 2020). This indicates that the availability of water has a considerable effect on the total solids and total soluble solids content of prickly pear fruit.

3.2.2. Total soluble solids

The soluble solids content of the fruits is an important factor in fruit juice production. Fruits with higher soluble solids content are more palatable than fruits with lower soluble solids content (Nunes et al., 2017). This is because fruits with higher soluble solids content typically have more intense sweetness and are juicier. The results in Table 3 showed that the total soluble solids (TSS) in the prickly pear pulp were 12.75 °brix. These results are within the range of the results reported by Dehbi et al. (2013), which were 11.33–15.47 °brix. It is comparable to the findings of Ibrahim et al. (2021), who reported that the TSS contents in purple and green cactus pear fruits were 12.68 and 11.75 °brix, respectively. This is an encouraging result, as it suggests that cactus pear fruits have a relatively consistent range of TSS content. The findings of Abou-Zaid et al. (2022), who reported that red prickly pear juice from Egypt had higher TSS contents than yellow prickly pear juice, which were 12.50 and 11.8 °brix, respectively, are comparable to the results found by Jambi (2017) in Saudi prickly pear fruit, which were 12.45%. These findings are in agreement with the results of our study, indicating that the TSS content in purple and green cactus pear fruits was within an acceptable range.

These results are higher than those found by Boudjouan et al. (2022), who found that the total soluble solid content in prickly pear fruit was 11.48 °brix, but they are lower than the results of Lekhuleni et al. (2021). Despite this, the results show a clear improvement from the previous studies in regards to total soluble solid content. They found that the TSS was 14.47, 13.02, and 14.45 °brix in orange, purple, and green prickly pear fruit from South Africa. It is also lower than the results found by El Finti et al. (2013) in Moroccan prickly pear fruits (17.03–19.75) °brix; Abdulkadir et al. (2022) in red cactus pear from the Eastern Tigray region, north Ethiopia (13.95) °brix; Reis et al. (2018) in cactus pears from Portugal (13.05–15.63%); and Gómez-Maqueo et al. (2020) in prickly pear fruit pulp from the Canary Islands (13.4–16) °brix. Despite the lower numbers found in our study, it is clear that there has been a steady improvement over time in the total soluble solid content of prickly pear fruit. It is also lower than the results of Koalaga et al. (2019), who reported that the total sugar content of prickly pear varieties in Northern Morocco ranged from 13.56–14.89 °brix. These results demonstrate a clear improvement from previous studies in the total soluble solid content of prickly pear fruit, with lower °brix readings than found in Morocco, Ethiopia, Portugal, and the Canary Islands.

3.2.3. Ascorbic acid

Ascorbic acid is one of the most important antioxidant compounds in prickly pear fruits. It had a good correlation with antioxidant activity content (De Wit et al., 2020). Prickly pear fruits are a good source of antioxidants such as vitamin C. Ascorbic acid is the reason why prickly pear fruits are good at fighting free radicals. The results in Table 3 show that the ascorbic acid content in prickly pear pulp was 28.41 mg/100 mL. These results are similar to those previously reported by Abdulkadir et al. (2022) in red and white cactus pear juice, which were 30.16 and 27.99 mg/100 g, respectively, and by Ibrahim et al. (2021) in purple and green cactus pear fruit, which were 42.45 and 39.7 mg/100 mL, respectively. Based on these results, prickly pear pulp has about the same amount of ascorbic acid as both red and white cactus pear juice and purple and green cactus pear fruit. Bourhia et al. (2020) reported that the Akria variety of prickly pear pulp has the highest ascorbic acid content (26.48 mg/100 g). A similar result was reported by Elshehy et al. (2020) for the ascorbic acid content in prickly pear fruit juice from Egypt (26.76 mg/100 g). A lower value of ascorbic acid was obtained in previous studies (El-Samahy et al., 2006; El-Samahy et al., 2009; Mohammed et al., 2014; Roghelia & Panchal, 2016). A higher value of ascorbic acid was found by Jambi et al. (2017) and Bareh et al. (2012) in prickly pear fruit from Saudi Arabia and Egypt, which was 32.75 and 32 mg/100 g, respectively. These studies showed that the amount of ascorbic acid in prickly pear fruit can vary depending on the geographic location, growing conditions, and seasonal variations.

3.2.4. Total sugar, reducing and non-reducing sugar

Prickly pear fruits should have a minimum sugar content of 13% in fruits destined for export (Inglese et al., 2002). The total sugars, reducing sugars, and non-reducing sugar content in prickly pear pulp included in this study were 11.78, 7.86, and 3.90%, respectively (Table 3). These results are similar to those found by Bareh et al. (2012). They found that the Egyptian prickly pear had 10.75% of total sugars, 8.24% of reducing sugars, and 2.71% of non-reducing sugars. This indicates that the sugar content of prickly pear fruits is fairly low compared to other fruits, although it still meets the minimum requirements for export.

A lower value of total sugar in prickly pear pulp (8.1%) was also reported (De Chávez et al., 1995), while Jambi (2017) found a higher value of total sugar in prickly pear fruit from Saudi Arabia was 14.53%. These variations in the results obtained in this study with the results of previous studies may be related to the difference in ripening degree, environmental conditions, and the genotype of the prickly pear plant. According to El-Gharras et al. (2006), the average reducing sugars in prickly pear pulp ranged from 117.24 to 152.26 g/kg, depending on fruit ripeness. As the ripeness of the fruit increases, so does the amount of reducing sugars, demonstrating that ripening plays a significant role in determining the total sugar content of prickly pears.

3.2.5. pH value and titratable acidity

Titratable acidity and pH value have great importance because the ratio of total soluble solids to acidity will affect flavor (Kgatla et al., 2010). The results in Table 3 show that the pH value of prickly pear pulp was 6.07. The pH value of prickly pear pulp obtained in this study was within the range reported by Reis et al. (2018) in Portuguese prickly pear fruit varieties (6.03-6.47) and by El-Samahy et al. (2006) and El-Samahy et al. (2009) in yellow prickly pear pulp (6.00–6.14). It is similar to those reported by Mohammed et al. (2014) for the pH in prickly pear fruits, which were 6.02. This suggests that the pH value of prickly pear pulp is pretty stable and does not change much based on things like variety or location. These results are higher than the results found by Dehbi et al. (2013), who found that the pH of prickly pear juice from Morocco was between 5.27 and 5.95. But they are lower than the results of Abdulkadir et al. (2022), who found the pH values in red and white pear cactus fruit from the Eastern Tigray region of Ethiopia were 6.15 and 6.29, respectively. They are also lower than the results of Gómez-Maqueo et al. (2020), who found that the pH in prickly pear fruit pulp from the Canary Islands ranged from 6.1 to 6.6. Lekhuleni et al. (2021) found that the pH value was 5.04, 5.48, and 6.04 in orange, purple, and green prickly pear fruit from South Africa. Therefore, the results from our study are in line with other studies that have been conducted, showing that prickly pear juice has a relatively low pH value.

The titratable acidity value of prickly pear pulp was 0.09% (Table 3). These results fell within the range of Dehbi et al. (2013) for prickly pear fruits from Morocco (0.05–0.10%) and also in the range of Koalaga et al. (2019) for prickly pear fruit varieties from Northern Morocco (0.07%–0.09%). This data shows that the titratable acidity of the prickly pear pulp from this study is the same as what was found in previous studies of prickly pear fruits from Morocco and Northern Morocco. But it was higher than those reported by Reis et al. (2018) in prickly pear from Portugal (0.05 and 0.07%), Dehbi et al. (2014) in prickly pear from Morocco (0.07%), El-Samahy et al. (2009), and El-Samahy et al. (2006) in prickly pear pulp from Egypt (0.05%) and (0.05–0.06%), respectively. Gómez-Maqueo et al. (2020) found 0.01% titratable acidity in Canary Island prickly pear fruit pulp. Lekhuleni et al. (2021) reported that the titratable acidity in South African orange, purple, and green prickly pear fruit was 0.03–0.06%.The prickly pear had a higher titratable acidity value of 0.22% (Mohammed et al., 2014). Nunes et al. (2017) reported that the titratable acidity in prickly pear varieties from the semi-arid region of the state of Bahia, Brazil, was 0.51%. The titratable acidity of Egyptian red and yellow prickly pear juice was 0.36–0.41% (Abou-Zaid et al., 2022), whereas the purple and green cactus pear fruit juice was 0.48–0.59% (Ibrahim et al., 2021). From these numbers, we can see that the titratable acidity of prickly pear fruit and juice can vary quite a bit between countries, states, and varieties.

3.2.6. °Brix/acidity ratio

The ratio of °brix/acidity is an important indicator for the quality, taste, and degree of maturity of prickly pear fruits. It measures the sweet-acid balance of foods. A high °brix/acidity ratio indicates there are more sugars than acids in the fruit (Nunes et al., 2017). The results in Table 3 showed that the °brix/acidity ratio in prickly pear pulp was 178.87. These results are higher than those reported by Dehbi et al. (2014) in yellow prickly pear pulp from Morocco (155.4) and higher than the results of Ibrahim et al. (2021) in purple (26.42) and green (19.94) cactus pear fruit, respectively. This suggests that the sweet-acid balance in prickly pear pulp from this region is higher than that found in other varieties of cactus pears.

It is also closer to the results of El-Samahy et al. (2006), who reported that the sugar/acidity ratio was in yellow prickly pear pulp from Ismailia (189.3), Qalyubia (175.1), and Sharkia (246.6) governorates, Egypt. These results are lower than the results found by El-Gharras et al. (2006). Based on what they found, the °brix/acid ratio went from 211.36 for mature green fruits to 268.92 for ripe fruits. It is also less than the value discovered by Bourhia et al. (2020) for Moroccan prickly pear pulp varieties, which ranged from 281.98 to 582.91 in the 2015 and 2016 seasons, respectively. It is also lower than the results of El-Samahy et al. (2009) for red prickly pear pulp, which was 224.07. These differences could be caused by differences in the stage of maturity, the environment, and the genotype of prickly pears.

Table 3. Chemical composition of prickly pear

Parameter	Mean	SD
Moisture (%)	86.83	2.76
Total solid (%)	13.17	2.77
TSS (°brix)	12.75	1.81
Total sugar (%)	11.78	5.09
Reducing sugar (%)	7.86	3.11
Non-reducing sugar (%)	3.90	2.87
Acidity (% as citric acid)	0.09	0.05
pH	6.07	0.68
Ascorbic acid (mg/100 mL)	28.41	11.29
TSS/Acidity ratio	178.87	107.89

Note. The values are the mean ± standard deviation (SD) measurements (n = 25).

4. Conclusions

Prickly pear fruits discovered in the wild in Yemen had a high pulp-to-seed ratio. The fruit juice had high soluble solids, and low acidity content. The results of the physical analysis of fruits and the chemical analysis of the fruit juice were in agreement with the results mentioned in previous studies from other countries. The mean weight of prickly pear fruits is lower than the value that must be reached in fruits destined for export. Further studies for prickly pear fruit properties from other regions in Yemen, especially irrigated prickly pear from some farms around Sana'a city, are needed.

Conflicts of interest. The authors said that none of them have a conflict of interest when it comes to this article.

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References

Abdulkadir, N., Solomon, W.K. & Woldetsadik, K. (2022). Optimization of heat treatment and pH of red and white pear cactus [*Opuntia ficus-indica* (l.) mill.] fruit juice using response surface methodology. Food Research, 6(3), 124–135.

Abou-Zaid, F.O.F., Ahmed, F.A. & Ibraheem, A.E.A. (2022). Using of prickly pear (*Opuntia* spp.) fruit juice and peels in cookies production. Alexandria Science Exchange Journal, 43(2), 239–248.

Anderson, E.F. (2001). The Cactus Family. Timber Press, Portland, p56-66.

Askar, A. & El-Samahy, S.K. (1981). Chemical composition of prickly pear fruits. Deutsche-Lebensmittel-Rundschau (Germany, F.R.), 77(8), 279–281.

Barbera, G., Carimi, F. & Inglese, P. (1992). Past and present role of the Indian-fig prickly-pear (*Opuntia ficus-indica* (L.) Miller, Cactaceae) in the agriculture of Sicily. Economic Botany, 9, 10–20.

Bareh, G.F., Shaheen, M.S. & Hussein, A.M.S. (2012). Production of good quality products from Egyptian prickly pear fruits. Journal of Applied Sciences Research, 8(11), 5494–5503.

Boudjouan, F., Zeghbib, W., Carneiro, J., Silva, R., Morais, J., Vasconcelos, V. & Lopes, G. (2022). Comparison study on wild and cultivated *Opuntia* sp.: Chemical, taxonomic, and antioxidant evaluations. Agriculture, 12, 1755.

Bourhia, M., Elmahdaoui, H., Ullah, R., Ibenmoussa, S. & Shahat, A. (2020). Physicochemical evaluation of the fruit pulp of *Opuntia* spp growing in the Mediterranean area under hard climate conditions. Open Chemistry, 18(1), 565-575.

Caplan, K. (1995). Merchandising, distribution and marketing nopalitos and cactus pears. In: Felker P. & Moss, J. (Eds), Proceedings of the Professional Association for Cactus Development First Annual Conference. p. 47-48.

Ciancaglinia, P., Santos, H.L., Daghastanli, K.R.P. & Thedie Jr., G. (2001). Laboratory exercises. Using a classical method of vitamin C quantification as a tool for discussion of its role in the body. Biochemistry and Molecular Biology Education, 29(3), 110–114.

Codex (1993). Standard for prickly pear. Codex. Stan. (186-1993).

Cota-Sánchez, J.H. (2016). Nutritional Composition of the Prickly Pear (*Opuntia ficus-indica*) Fruit. In: *Nutritional Composition of Fruit Cultivars*, Simmonds, M.S.J. & Preedy, V.R. (Eds.), Academic Press, 691–712.

de Chávez, M.M., Chávez, A., Valles, V. & Roldán, J.A. (1995). The nopal: a plant of manifold qualities. Plants in Human Nutrition, 77, 109–134.

De Wit, M., Du Toit, A, Osthoff, G. & Hugo, A. (2020). Antioxidant content, capacity and retention in fresh and processed cactus pear (*Opuntia ficus-indica* and *O. robusta*) fruit peels from different fruit-colored cultivars. Frontiers in Sustainable Food Systems, 4, 133.

Dehbi, F., Hasib, A., Tilaoui, M., El Batal, H., Zaki, N., Ouatmane, A., Jaouad, A. & Zyad, A. (2013). Bioactive constituents, antioxidant activity and *in vitro* cancer cell cytotoxicity of Moroccan prickly pear (*Opuntia ficus indica* L.) juices. Journal of Natural Sciences Research, 3(14), 12–20.

Dehbi, F., Hasib, A., Ouatmane, A., Elbatal, H. & Jaouad, A. (2014). Physicochemical characteristics of Moroccan prickly pear juice (*Opuntia ficus indica* L.). International Journal of Emerging Technology and Advanced Engineering, 4(4), 300–306.

EL Finti, A., EL Boullan, R., Fallah, M., Msanda, F. & EL Mousadik, A. (2013). Assessment of some agro-technological parameters of cactus pear fruit (*Opuntia ficus-indica* Mill) in Morocco cultivars. Journal of Medical Plants, 7(35), 2574–2583.

El-Gharras, H., Hasib, A., Jaouad, A. & El-Bouadili, A. (2006). Chemical and physical characterization of three cultivars of Moroccan yellow prickly pears (*Opuntia ficus-indica*) at three stages of maturity. Ciencia e Tecnologia de Alimentos, 5(2), 93–99.

El-Samahy, S.K., Abd El-Hady, E.A., Habiba, R.A. & Moussa, T.E. (2006). Chemical and rheological characteristics of orange-yellow cactus-pear pulp from Egypt. Journal of the Professional Association for Cactus Development, 8, 39–51.

El-Samahy, S.K., Youssef, K.M. & Ayoub, T.E.M. (2009). Production ice cream with concentrated cactus pear pulp: A preliminary study. Journal of the Professional Association for Cactus Development, 11, 1–12.

Elshehy, H.R., El Sayed, S.S., Abdel-Mawla, E.M. & Agamy, N.F. (2020). Nutritional value of cladodes and fruits of prickly pears (*Opuntia ficus-indica*). Alexandria Journal of Food Science and Technology, 17(1), 17–25.

Gómez-Maqueo, A., Antunes-Ricardo, M., Welti-Chanes, J. & Pilar Cano, M. (2020). Digestive stability and bioaccessibility of antioxidants in prickly pear fruits from the Canary Islands: Healthy foods and ingredients. Antioxidants, 9,164.

Gurrieri, S., Miceli, L., Lanza, C.M., Tomaselli, F., Bonomo, R.P. & Rizzarelli, E. (2000). Chemical characterization of Sicilian prickly pear (*Opuntia ficus indica*) and perspectives for the storage of its juice. Journal of Agricultural and Food Chemistry, 48(11), 5424–5431.

Ibrahim, G.E., Elwakeelb, M. & Hussein, A.M.S. (2021). Evaluation of quality attributes antioxidant activity and volatile compounds of two cactus pear juices blended with guava juice. Egyptian Journal of Chemistry, 64(5), 2613–2622.

Inglese, P., Barbera, G., La Mantia, T. & Portolano, S. (1995). Crop production, growth, and ultimate size of cactus pear fruit following fruit thinning. HortScience, 30(2), 227–230.

Inglese, P., Basile, F. & Schirra, M. (2002). Cactus pear fruit production. In: *Cacti: Biology and Uses*, Nobel P.S. (ed.), Berkeley, University of California Press, p163–183.

Jambi, H.A. (2017). Physiochemical, microbiological and sensory properties of probiotics prickly pear permeate beverages. Middle East Journal of Applied Sciences, 7(4), 745-754.

Karababa, E., Coşkuner, Y. & Aksay, S. (2004). Some physical fruit properties of cactus pear (*Opuntia* spp) that grow wild in the Eastern Mediterranean region of Turkey. Journal of the Professional Association for Cactus Development, 6, 1-9.

Kgatla, T.E., Howard, S.S. & Hiss, D.C. (2010). The effects of processing and preservation on the sensory qualities of prickly pear juice. World Academy of Science, Engineering and Technology, 4(8), 520–527.

Koalaga, D.Y., Messaoudi, Z., Ibriz, M. & Haddou, L.A. (2019). Effect of altitude on the pomological and physico-chemical traits of dallahia prickly pear fruits in Northern Morocco. European Journal of Scientific Research, 154(4), 471–482.

Kumar, K., Singh, D. & Singh, R.S. (2018). Cactus pear: Cultivation and Uses. CIAH/Tech./Pub. No. (73), 38, ICA R-Central Institute for Arid Horticulture, Bikaner, Rajasthan, India.

Lekhuleni, I.L.G., Kgatla, T.E., Mashau, M.E. & Jideani, A.I.O. (2021). Physicochemical properties of South African prickly pear fruit and peel: Extraction and characterisation of pectin from the peel. Open Agriculture, 6, 178–191.

Mohammed, S.A., Hussein, A.M.S. & Ibraheim, G.E. (2014). Physicochemical, sensorial, antioxidant and volatile of juice from prickly pear with guava or mandarin. International Journal of Food and Nutritional Sciences, 3(6), 44–53.

Nunes, V.X., Nunes, N.X., Londe, L.N., de Oliveira, C.G., Inoue, N.A.M., Rocha, S.S. & Calaes, J.G. (2017). Physico-chemical characterization of prickly pear (*Opunicia ficus indica*) in the semi-arid region of Bahia State, Brazil. African Journal of Agricultural Research, 12(51), 3537-3541.

Osuna-Martínez, U., Reyes-Esparza, J. & Rodríguez-Fragoso, L. (2014). Cactus (*Opuntia ficus-indica*): A Review on its antioxidants properties and potential pharmacological use in chronic diseases. Natural Products Chemistry and Research, 2, 153.

Patil, K.V. & Dagadkhair, A.C. (2019). Physicochemical characteristics and antioxidant potential of *Opuntia* fruit: A review. The Pharma Innovation Journal, 8(6), 376-380.

Reis, C.M.G., Gazarini, L.C. & Ribeiro, M.M. (2018). Fruit production from *Opuntia ficus-indica* ecotypes in comparison to commercial Italian clones. Horticultural Science (Prague), 45, 92–100.

Roghelia, V. & Panchal, J. (2016). Physicochemical characteristics of cactus pear fruits. Journal of Pharmaceutical, Chemical and Biological Sciences, 4(1), 119-125.

Yahia, E.M. & Sáenz, C. (2011). Cactus pear (*Opuntia* species). In: *Postharvest biology and technology of tropical and subtropical fruits* (p.290-331e). Woodhead Publishing.

Zegbe, J.A. (2020). Quality and storability of cactus pear fruit as improved by supplemental irrigation. Journal of the Professional Association for Cactus Development, 22(1), 1-17.