



ORIGINAL ARTICLE

Husk Cherry: Nutritional attributes, bioactive compounds and technological applications



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Abstract Husk cherry (*Physalis pruinosa*; L) is a tropical fruit commonly grown in the Mediterranean region, and widely consumed fresh in most countries of the world. To enhance our knowledge about this promising fruit, the technological, therapeutic, and nutritional quality attributes of the raw fruits were investigated. The fruit had an orange yellowish color and a mild sweetness, with a pulp yield of 93.40 % (w/w) and a juice yield of 64.45 % (v/w). It contains high ratios of total sugar (41.65%), protein (14.56%), crude fibers (11.59 %), ascorbic acid (40.17 mg/100 g), β -carotene (64.78 $\mu\text{g/g}$), total phenols (178.53 mg gallic acid 100 g^{-1}), anthocyanin (7.01 μg cyaniding-3-glucoside equivalents 100 g^{-1}), flavonoids (6.69 mg quercetin g^{-1}), and chlorophylls (19.03 $\mu\text{g g}^{-1}$). These fruit showed high antioxidant activities, which were found using DPPH and ABTS assays, and could be considered as a good source of antioxidants. The fruit contained several minerals, including potassium, phosphorus, sodium, and magnesium. The major amino acids in the fruit pulp were glutamic acid, aspartic acid, arginine, phenylalanine, proline, valine and alanine. The main polyphenols detected in the fruits were gallic acid, 4-hydroxybenzoic acid, benzoic acid, catechol, ellagic acid, chlorogenic acid, and epicatechin. Several flavonoids can be obtained in high concentrations, such as naringenin, luteolin, and rutin. Six functional food products (juice, jelly, jam, candied fruits, chocolate-coated dried fruits, and fruit leather) were manufactured using husk cherry fruits. The quality attributes of prepared products were determined. The highest crude fiber, ascorbic acid, β carotene, and total sugar compositions were found in chocolate-coated dry fruit products. All the manufactured products were well palatable amongst 25 trained panelists. The findings of this study confirmed the nutritional and technological potential

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of husk cherry fruits, which might be used effectively within the development of some functional products for food industries.

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1. Introduction

Physalis pruinosa is a member of the Solanaceae family of approximately 2800 species and 85 genera and is known by many English names, including husk cherry, pineapple tomatillo, and Cape gooseberry. It is a promising tropical plant, which is grown in Australia, California, New Zealand, India, South Africa, and Egypt (Somkuwar 2014; Nawirska-Olszańska et al., 2017). *P. pruinosa* fruit are commonly consumed fresh in the Middle East. In some countries, small industries have sprouted up around these fruit, but they are yet to gain widespread commercial success (Thuy et al., 2020). In the last few decades, many countries have started processing tropical fruits. This development has led to the expansion of fruit industries in fruit-growing countries, which are attempting to encourage successful production strategies for both domestic and export markets (Mazova et al., 2020). *P. pruinosa* fruit have several uses in daily consumption in several countries, including in salad decorations and preparing deserts, cooked meals, fresh juices, decorated jelly, and natural preservative (Mazova et al., 2020; Ramadan et al., 2008; Ramadan and Mörsel, 2003).

The shelf life of *P. pruinosa* fruit grown in Egypt is relatively short, and they can be stored frozen. The fruit have an attractive tropical golden color with a juicy texture and appealing flavor and taste. The productivity of *P. pruinosa* crops is promising because the fruits are produced in 3–4 months under conditions of low irrigation and poor soils, making it suitable for small-scale commercial production in temperate climates (Singh et al., 2014). Previous investigations have been conducted on the processing of other *Physalis* species, which are commonly grown as edible fruits and used in desserts, juice processing, and appetizers (Sharoba and Hassanien, 2010; Aamer, 2018; Ramadan and Mörsel, 2003). However, no studies have been conducted on the processing of *P. pruinosa* fruits to produce jam, candied fruit, chocolate-coated dry fruit, juice, jelly, and fruit leather.

The fruits of closely related *Physalis* species have also been used in traditional medicine for the treatment of throat infections, amoebas, and intestinal parasites, and they have diuretic, kidney albumin reduction, antiseptic, and antiasthmatic applications (Sharoba and Hassanien, 2010). Additionally, other studies have revealed that *P. peruviana* is used for the treatment of malaria, dermatitis, and rheumatism (Singh et al., 2014). Previous investigation of *P. pruinosa*, which included the production of dry fruit, revealed that the fruit contain a high proportion of total sugar (54.22%), titratable acidity (1.72%), high ascorbic acid (178.88 mg/100 g), and moderate ash composition (5.98%) (Abou-Farrag et al., 2013). However, the study did not investigate the possibility of obtaining products other than dried fruit products. Previous investigation of *P. peruviana* revealed a low ash (2.98 %) and protein (1.66 %) content, a moderate antioxidant ratio (57.67

%), and a moderate phenolic composition (145.22 mg gallic acid /100 g) (İzli et al., 2014). Another study on *P. pubescens* fruit revealed high protein (13.14%), low pectin (0.47%), moderate polyphenols (125.04 mg tannic acid/100 g), and lower total sugars (32.43%) (El Sheikha et al., 2008). *P. peruviana* fruit has strong antioxidant and anticancer properties (Mier-Giraldo et al., 2017). Additionally, the leaves, calyces, and fruit of other *Physalis* species, such as *P. patula*, *P. subulata*, *P. solanacea*, *P. hederifolia*, and *P. angulata*, contain several phenolic acids and have noticeable antioxidant activities (Medina-Medrano et al., 2015). However, the health benefits and nutritional values of *P. pruinosa* fruit are understudied.

Considering the health benefits of *P. pruinosa*, very limited attention has been given to prolonging the shelf life of its fruit in food industries. There is currently no available information about the nutritional, chemical, and sensory characteristics of prepared food stuff from *P. pruinosa*. This study sheds light mostly on the fruit of the husk cherry (*Physalis pruinosa*), which is already widely consumed fresh in most countries worldwide. This may explain why surplus fruits record post-harvest losses due to weevil infection and poor handling during its peak season. As a result, there is a need to investigate efficient and affordable food processing methods that can be used to process surplus fruits into shelf-stable products such as juice, jelly, jam, and other similar products that are safe, nutritious, inexpensive, well preferred by consumers, and economically viable alternatives that will minimize post-harvest losses. The main aims of the study are to assess the bioactive compounds and nutritional quality attributes of husk cherry (*P. pruinosa*) and to develop six food products, including jam, candied fruit, chocolate-coated dry fruit, juice, jelly, and fruit leather, of *P. pruinosa*, and to assess the most significant attributes that control their quality characteristics. This technological processing of these fruits may develop continuous supply to the local and international markets with new products of high nutritional and economic value.

2. Materials and methods

2.1. Chemicals and plant material

All chemicals used in this study were of analytical grade and purchased from Sigma Aldrich (Berlin, Germany). Fresh husk cherry (*P. pruinosa* L) fruits (Fig. 1) were purchased from the local market in Damietta, Egypt in October 2019. Samples were identified by Prof. Elansary at the Faculty of Agriculture, University of Alexandria. The fruits were sorted and then washed with running tap water. The entire clean, de-husked fruits were used in the manufacture of jam, candied fruit, and chocolate-coated dry fruit, while the fruit pulp was used in the manufacture of juice, jelly, and fruit leather. Sugar, chocolate, glass, bottles, and jars were purchased from Damietta hypermarkets.



Fig. 1 Whole fruit and berries of husk cherry (*P. pruinosa*, L.); (Photo by E. A. Mahmoud).

2.2. Physicochemical methods

The measured technological properties of *P. pruinosa* fruit included the percentage of the husk, pulp yield, juice yield, skin and seeds, and juice ratio, which were determined using a digital top-loading balance (Radwag PS 6000/C1).

The physical properties of the fruit, including average weight (g fruit⁻¹), fruit average width (cm fruit⁻¹), fruit average length (cm fruit⁻¹), and fruit index (width length⁻¹), were measured in micrometers. The number of fruit kg⁻¹, number of seeds fruit⁻¹, and weight of one thousand seeds (g) were determined (Kramer and Twigg, 1971; Polat and Caliskan, 2008). The pH values of fresh fruit and prepared products were measured (A.O.A.C., 2005) using a glass electrode pH meter (SX811-BR Portable pH Meter, USA). Total soluble solids (TSS %) were determined using a refractometer (Atago, Japan) at 20 °C following the Association of Official Analytical Chemists (AOAC) (2005). Total soluble solids (TSS) and titratable acidity were used to measure the sugar to acid ratio (Lacey et al., 2001). Color was assessed using a Lovibond Schofield Tintometer (model IA, USA) following Ranganna (1977).

2.3. Analytical methods

2.3.1. Nutritional properties

Moisture, crude protein, ether extract, crude fiber, ash, total sugar, nitrogen-free extract, total titratable acidity (as citric acid % w/v), and ascorbic acid were determined following the AOAC (2005). The calorific value was 9 Cal gram⁻¹ for fat and 4 Cal gram⁻¹ for protein and carbohydrate (Joint F. A.O./W.H.O. expert committee on nutrition, 1970). The total pectin content was determined following Horwitz (1982).

2.3.2. Mineral composition

Thirteen key minerals (5 Macro-minerals, 5 Micro-minerals, and 3 Ultra-trace minerals) were assayed. Sodium (Na) and potassium (K) were determined using a Gallenkamp flame analyzer (Model PEP7, U.K.). Other minerals were measured using a Perkin Elmer atomic absorption spectrophotometer (Perkin Elmer 932AA, Australia), following AOAC (2005). Total phosphorus was estimated calorimetrically at 660 nm (Taussky and Shorr, 1953).

2.3.3. Phytochemical compounds

Total chlorophyll and β -carotene content ($\mu\text{g/g}$) were determined in the acetone extract (80%) using a spectrophotometer

at 652 and 440 nm, respectively (A.O.A.C., 2005). Total flavonoids, phenol content, and antioxidant activities were determined in the methanol extract (80%) using a spectrophotometer. The methanol extract was formed by blending 1 g of sample with 10 mL of methanol (80%) and stirring it for 24 h at room temperature before filtering. The total flavonoid content (mg quercetin g⁻¹) was estimated using a spectrophotometer at 510 nm (Zakaria and Tan, 2013). Then, the total polyphenols content (mg gallic acid 100 g⁻¹) was determined using the Folin-Ciocalteu method with a spectrophotometer at 765 nm (Maurya and Singh, 2009). Antioxidant activity was determined using two radical scavenging spectrophotometric assays of DPPH (2, 2-diphenylpicrylhydrazyl) at 517 nm (Park et al., 2010) and ABTS (2, 2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) at 734 nm (Re et al., 1999; Nawirska-Olszańska et al., 2013). The total anthocyanins composition (μg cyaniding-3-glucoside equivalents 100 g⁻¹) was determined in the methanol containing 1% (v/v) HCl using a spectrophotometer at 520 and 700 nm (Stanciu et al., 2010). The total tannins content (mg tannic acid 100 g⁻¹) was determined in ethanol extract (70%) using a spectrophotometer at 700 nm using Folin-Denis reagent (Saxena et al., 2013).

2.3.4. Carbohydrate assay

Soluble sugars were extracted sequentially with three portions of boiling aqueous-ethanol 80%. The supernatant was mixed, and the ethanol was evaporated using a rotary evaporator (Eyela, N-1300S-W 115 V) at 45 °C until 15 mL, which was diluted to 50 mL with distilled water before being filtered to 0.2 mm for chromatographic assay. The separation was performed on an ion chromatograph (Dionex DX600) equipped with a column filled with polystyrene-divinylbenzene balls ranging in size from 5 to 10 μm , an anion-exchange column (250 mm \times 4 mm, Dionex Carbo-Pac PA1), and an amperometric detector (PAD) (Zhang and Ritenour, 2016).

2.3.5. Amino acids assay

After 24 h of hydrolysis with 6 N HCl containing 0.1 % mercaptoethanol at 100 °C, amino acid compositions were measured by liquid chromatography using a Beckman amino acid analyzer 119CL-GB (Moore and Stein, 1963). Tryptophan was destroyed by acid hydrolyses. The colorimetric method was used to calculate the tryptophan in a Ba (OH)₂ hydrolysate (Lucas and Sotel, 1980).

2.3.6. Fatty acid assay

Fatty acid methyl esters were prepared as described before (A. O.A.C., 2012). Then, they were directly injected into the gas chromatograph (Agilent, Model GC6890), which was equipped with a flame-ionization detector (FID). A Supelcowax10 capillary column (SGE, Courtaboeuf, France; 0.32 mm internal diameter \times 30 m length, 0.25 m film thickness) was used. Helium was used as the carrier gas, with a flow rate of 1 mL.min⁻¹ and a splitting ratio of 1/100. The injector temperature was 250 °C and that of the FID was 270 °C. Fatty acids were identified by comparing them to commercially available fatty acid standards (Mannion et al., 2018). The peaks were identified using retention times and comparing them to standards.

2.3.7. Polyphenol analyses

For the high performance liquid chromatography (HPLC) analyses, the methanolic extracts of *P. pruinosa* fruit pulp were prepared by sonication of 0.5 g dry weight in 8 mL of methanol (HPLC grade, Merck). Next, the extracts were fractionated using HPLC Agilent 1100 (Agilent, Germany), equipped with column: Hypersil BDS-C18, 5 μ m (150 mm \times 4.6 mm, Altech, USA), UV-Vis (G1314B) detector operated at 254 (catechins and phenolic acids) and 273 nm (flavonoids). Elution was carried out with flow rate 0.3 mL/min at 25 °C and an injection volume: 10 μ L. Mobile phase: solvent A: (acetic acid/ acetonitrile) (0.5/ 99.5, v/ v), and solvent B: acetic acid/ water (0.5/ 99.5, v/ v) were de-aerated in an ultrasonic bath after being filtered through 0.45- μ m Nylon filters. The gradient program was as follows: 0–20 min 100% B; 20–35 min 100–80% B; 35–55 min 80–60% B; 55–70 min 60–0% B; 70–75 min 0% B; 75–80 min 0–100% B; 80–90 min 100% B. The method was validated for range, precision, linearity, system suitability, sensitivity, and specificity (Niranjan et al., 2009). Agilent ChemStation software was used to integrate the data. The retention times and UV-VIS spectra of phenolic compounds were compared to those of authentic Sigma Aldrich standards (Carranco et al., 2018).

2.4. Technological methods

P. pruinosa samples were manually de-husked, sorted to pick mature fruit and graded according to color, before being washed with tap water. For the duration of the experiment, whole fresh fruits pulp of *P. pruinosa* were stored at -18 °C. The de-husked fruit were divided into three sections and processed as follows:

First Section: Canned and chocolate-coated dry fruit were processed using whole fruit.

Second Section: Using a fruit pulper (Kenwood AT644, Japan), fruit were pulped, and the pulp was used to make jam. The prepared pulp was cold stored at -18 °C until it was used.

Third section: The extracted pulp was filtered through a cheese cloth to separate the seeds and skins before it was used to produce juice, jelly, and fruit leather. The fruit juice was cold stored at -18 °C until it was used.

Fig. 2(A&B) shows the detailed flow sheet used to prepare the selected products. All products in this study were manufactured at the Department of Food Industries, Damietta University, Egypt.

2.5. Sensory evaluation

Sensory evaluation of prepared *P. pruinosa* products was carried out using 25 trained panelists (11 females and 14 males, aged 23–50 years) with at least three years of experience. All panelists were staff, faculty and post grad students at the Food Industries Department, Damietta University, Egypt. Following a 60-minute orientation session, the panelists began documenting the aims of the study, vocabulary, as well as each sensory attribute and key points on the scale. The panelists were shown the 3-digit coded samples simultaneously and assessed them in a random order. A one-minute interval between samples was required to limit carryover effects. Panelists were provided with a drinkable water to clean their

mouths after assessing each sample to limit taste interference (Iwe, 2002). For juice, jam, and jelly, the samples were packaged in coded transparent glass jars; however, canned and chocolate-coated dry fruit, and fruit leather were kept in coded plates filled with aluminum foil. All samples were shown under white lightening and the room temperature was set to 25 °C. The sensory quality attributes of the samples were general appearance, colour, taste, odor, texture, homogeneity, and overall palatability. The panelists were asked to rate the above attributes according to a hedonic scale of 1 (extremely dislike), 2–4 (dislike), 5–6 (fair), 7–8 (like), and 9–10 (extremely like) and the mean scores of the three evaluations were calculated. All sensory experiments were conducted under the academic supervision of a Food Industries Department.

2.6. Statistical analysis

The results were presented as means of triplicates \pm standard deviation (SD). A one-way analysis of variance (ANOVA) with post-hoc Tukey's Honestly Significant Difference (Tukey HSD) was performed using SAS software (Ver. 9.4) to test for significance variations between sample means at $p < 0.05$.

3. Results and discussion

3.1. Physical and technological properties of fresh *P. Pruinosa* fruit

The average weight, width, length, and fruit index of fresh *P. pruinosa* fruit were 3.91 g, 1.99 cm, 1.89 cm, and 1.05, respectively (Table 1). Each 1 kg sample contained an average of 275 fruit, each fruit contained an average of 203 seed and the average weight of 1000 seeds was 2.12 g. The fresh fruit husk comprised 6.60%, the pulp yield percentage was 93.40%, and the juice yield was 64.45%. Due to the high skin and seeds ratio (35.55%), the juice ratio (1.81/1) was low. Published work on this species is very limited. Therefore, this is the first comprehensive technological investigation of this species. Previously, one research group found that the fruit of *P. pruinosa* has comparable fruit characteristics and number of fruits kg^{-1} , but they did not measure juice parameters, such as the juice yield and ratio (Abou-Farrag et al., 2013). Other studies on another species of the same genus, e.g., *P. peruviana*, have revealed lower numbers of fruit kg^{-1} , higher husk content (8.02%), lower seed and skin ratio (21%), higher fruit weight (4.69 g), and higher ratio of extracted juice (79%) (Amer, 2018). Another study on *P. peruviana* showed comparable mass of fruit (3.09 g) and fruit diameters (İzli et al., 2014). The variations among these findings might be attributed to species, harvest time, climate, cultivation conditions, and growing area.

3.2. Nutritional and phytochemical properties of *P. Pruinosa* fruit

The fruit samples contained high ratios of protein (14.56%), total sugar (41.65%), and crude fibers (11.59 %) as well as a moderate moisture ratio, as shown in Table 2. A previous study on *P. pruinosa* revealed a higher value of total sugar (54.22%) and comparable ash composition (5.98%) (Abou-Farrag

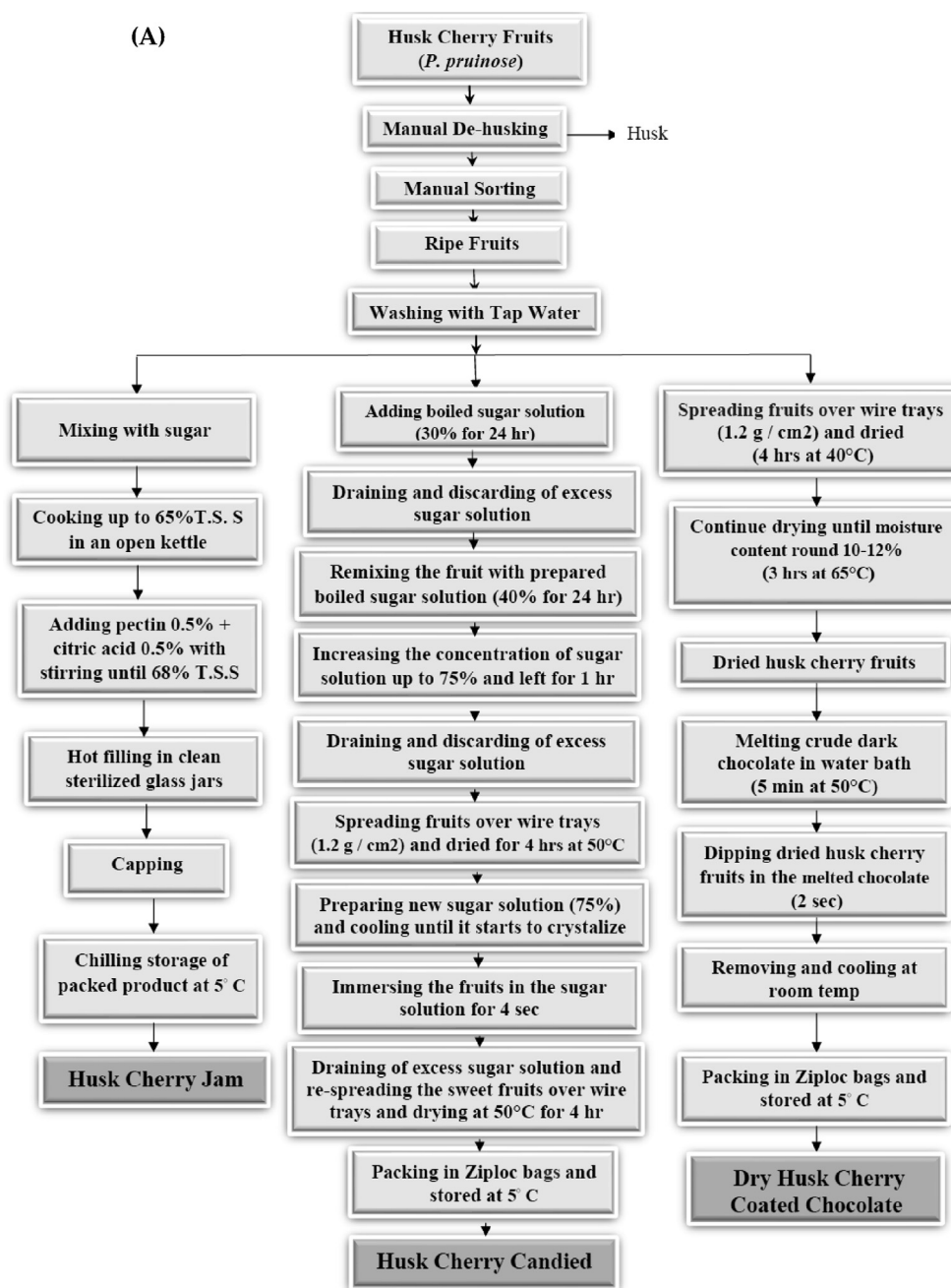


Fig. 2 Flow sheet of prepared Husk cherry (*P. pruinosa*) products. **A:** products manufactured from whole Husk cherry fruits (jam, candied fruit, and chocolate-coated dry fruit); **B:** products manufactured from Husk cherry puree (juice, jelly, and fruit leather).

et al., 2013). The fruits contained total phenols (178.53 mg gallic acid 100 g^{-1}), anthocyanin (7.01 μg cyaniding-3-glucoside equivalents 100 g^{-1}), flavonoids (6.69 mg quercetin g^{-1}), and chlorophylls (19.03 $\mu\text{g g}^{-1}$). These data were in agreement with El-Beltagi et al. (2019) who found that total phenols, and total flavonoids in *P. peruviana* fruits were 125.44 mg gallic acid /g, and 6.39 mg quercetin /g; respectively. Additionally, the fruits showed high antioxidant activities, as shown by the DPPH (567.12 μg trolox equivalent g^{-1}) and ABTS (534.03 μg trolox equivalent g^{-1}) assays (Table 2). The results showed that *P. pruinosa* could become a potential source of bioactive compounds

that might be used as natural food additives rather than chemical artificial additives. Different species such as *P. peruviana* revealed lower ash (2.98 %) and protein (1.66 %) contents, a moderate antioxidant ratio (57.67 %), and lower phenolic composition (145.22 mg gallic acid /100 g) (İzli et al., 2014). The data was consistent with Ramadan and Mörşel (2007), that fresh cape gooseberry had 78 % antioxidant activity. According to Jéssica et al. (2013), antioxidant activity might be correlated with the quantity of total flavonoid, total phenolic, β -carotene, and vitamin C content since these compounds function as scavengers of free radicals through oxidation.

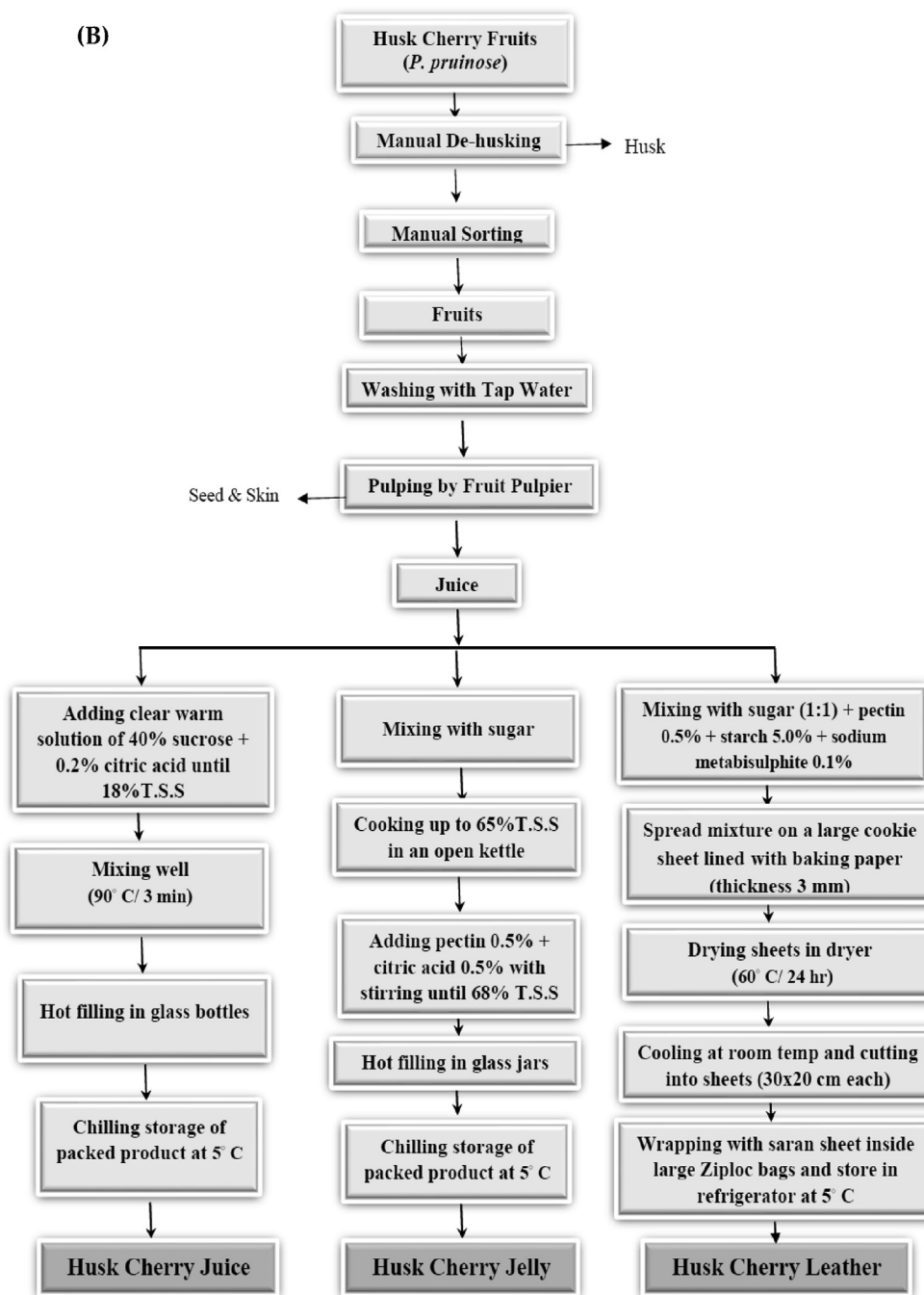


Fig. 2 (continued)

3.3. Amino and fatty acids profiles of *P. Pruinosa* fruit

The amino acid analyses of the fruit showed high contents of total essential amino acids (27.26 g 100 g⁻¹), total semi-essential amino acids (11.45 g 100 g⁻¹), and total non-essential amino acids (57.10 g 100 g⁻¹) as presented in Table 3. The total amino acid composition was 95.81 g 100 g⁻¹, and it contained several essential amino acids, such as phenylalanine, valine, leucine, threonine, lysine, isoleucine, and tryptophan, two semi-essential amino acids, including arginine and histidine, and non-essential amino acids, including glutamic acid,

aspartic acid, proline, alanine, and tyrosine. The major amino acids in the current study were glutamic acid (19.82%), aspartic acid (17.49%), and arginine (9.44%). These amino acids were found at higher concentrations than for other species, such as *P. pubescens*. Interestingly, higher amounts of specific amino acids, such as the arginine, were found in the sampled *P. pruinosa* fruit than in other congeneric species in previous studies.

To the best of our knowledge, the fatty acid composition of the *P. pruinosa* fruit of this species had not been previously reported, and the current study revealed high ratios of satu-

Table 1 Technological and physical properties of fresh *P. pruinosa* fruit.

Technological properties (%w/w)	
Husk	6.60 ± 1.11
Pulp yield	93.40 ± 1.23
Juice yield	64.45 ± 0.78
Skin and seeds	35.55 ± 0.89
Juice ratio (Juice yield/seeds + skin)	1.81/1 ± 0.09
Physical properties	
Number of fruits per kilogram	275.00 ± 2.06
Fruit average weight (g)	3.91 ± 0.32
Fruit average width (cm)	1.99 ± 0.94
Fruit average length (cm)	1.89 ± 1.03
Fruit index (width/length)	1.05 ± 1.42
Number of seeds per fruit	203 ± 0.79
Weight of one thousand seeds (g)	2.12 ± 0.52

Values are shown as the mean ± standard deviation, n = 30.

Table 2 Nutritional and phytochemical properties of fresh *P. pruinosa* fruit.

Nutritional properties (%w/w)	
Moisture	81.83 ± 1.34
Crude protein (T.N × 6.25) **	14.56 ± 1.12
Ether extract**	9.34 ± 0.53
Crude fiber**	11.59 ± 0.92
Ash **	5.84 ± 0.26
Total sugar**	41.65 ± 0.85
Nitrogen-free extract **	18.67 ± 0.86
Total Pectin content **	0.74 ± 0.11
Energy (kcal/100 g) **	308.90 ± 0.93
Phytochemical properties	
Total chlorophyll (µg g ⁻¹) *	19.03 ± 0.94
Total anthocyanins (µg cyaniding-3-glucoside equivalents 100 g ⁻¹) *	7.01 ± 0.13
Total phenol content (mg gallic acid 100 g ⁻¹) **	178.53 ± 0.16
Total flavonoids (mg quercetin g ⁻¹) **	6.69 ± 0.32
Antioxidant activity	
DPPH assay (µg trolox equivalent g ⁻¹) *	567.12 ± 0.61
ABTS assay (µg trolox equivalent g ⁻¹) *	534.03 ± 0.24

Values are shown as the mean ± standard deviation, n = 3; * on fresh weight basis ** on dry weight basis; DPPH=2, 2-diphenyl-1-(2, 4, 6-trinitrophenyl)-hydrazonyl, ABTS=2, 2'-azino-bis; (3-ethylbenzothiazoline-6-sulphonic acid).

rated, monounsaturated, and polyunsaturated fatty acids, including palmitic, stearic, arachidic, oleic, palmitoleic, nervonic, linoleic, and linolenic acids (Table 3). The fruit contained saturated fatty acids (14.04%), such as palmitic, stearic, and arachidic acids, monounsaturated fatty acids (26.37%), such as oleic, palmitoleic, and nervonic acids, and polyunsaturated fatty acids (59.59%), such as linoleic and linolenic acids. The lack of short-chain fatty acids (such as caproic and caprylic acid) may indicate that there is no undesirable odor from *P. pruinosa*, which is one of the most important technical properties of the oil (Norma et al., 2004). The fruit contained considerable amounts of essential amino and fatty

acids, which cover much of the dietary reference intake of World Health Organization (WHO)/ Food and Agriculture Organization (FAO)/United Nations University (UNU) for 2007, indicating that these fruits are highly suitable for daily consumption (WHO/FAO/UNU's, 2007).

3.4. The mineral composition of *P. Pruinosa* fruits

In the investigated fruit, several minerals were found including potassium, phosphorus, sodium, and magnesium, as shown in Table 4. The highest mineral contents were of potassium (547.50 mg 100 g⁻¹), phosphorus (156.87 mg 100 g⁻¹), and sodium (111.83 mg 100 g⁻¹). Sodium and potassium can regulate the body's blood pressure and water balance. Other trace and ultra-trace elements were found, including iron, zinc, cobalt, and boron. This is the first report on the mineral composition of *P. pruinosa* fruit. These minerals play a key role in the composition of teeth and bones, promote enzymatic processes, aid in regulation of body fluid compositions, and contribute to metabolisms as vitamins and hormones (Cobaleda-Velasco et al., 2017). Studies on *P. peruviana* found that potassium and magnesium were the major elements in the fruit pulp (689.2 ppm and 65.3 ppm of fresh weight, respectively) (Aamer, 2018). The mineral composition of the fruit pulp included a considerable amount of the WHO/FAO/UNU's 2004 recommended daily intake, indicating that these fruits are highly suitable for daily consumption (DRIs, 2004).

3.5. The polyphenolic profile of *P. Pruinosa* fruits

The methanolic extract of the fruit pulp contained twenty-nine polyphenols (Table 5). The major polyphenols were gallic acid, 4-hydroxybenzoic acid, benzoic acid, catechol, ellagic acid, chlorogenic acid, and epicatechin. Other estimated phenolic compounds, such as catechin, vanillic acid, and caffeic acid, were present at lower amounts. However, some flavonoids were available at high quantities, such as naringenin, luteolin, and rutin (Fig. 3).

Previous investigation of *P. peruviana* fruit from Poland using fluorometry and Fourier transform infrared (FT-IR) revealed the availability of some polyphenols, such as gallic acid, ferulic acid, hesperidin, tannic acid, caffeic acid, and quercetin (Namięśnik et al., 2014). In another study, the leaves, fruits, and calyces of five wild *Physalis* species (*P. angulata*, *P. subulata*, *P. solanacea*, *P. patula*, and *P. hederifolia* var *hederifolia*) were investigated using HPLC with a diode-array detector (HPLC-DAD) and contained some polyphenols, such as quercetin-3-O-glycoside and kaempferol-3-O-glycoside (Medina-Medrano et al., 2015). HPLC-DAD on *P. angulata*, which is a medicinal plant from Mexico, revealed that the calyx of the plant contained chlorogenic acid, while the leaves and stems contained quercetin-3-O-glycoside (Cobaleda-Velasco et al., 2017). To the best of our knowledge, this is the first investigation of the polyphenolic profile of *P. pruinosa* fruit using HPLC.

3.6. The physicochemical, color, and nutritional properties of prepared *P. Pruinosa* food products

The physicochemical, color, and nutritional properties of *P. pruinosa* fruit and prepared products, including juice, jelly,

Table 3 Amino and fatty acids profile of *P. pruinosa* fruit pulp.

Amino acid	Content (g/100 g of protein)	DR (g/day)	Fatty acid	Content (%of total fatty acids)	DR (g/day)
Phenylalanine	4.90 ± 0.64	1.90	C _{12:0} Lauric	0.30 ± 0.23	
Valine	4.51 ± 0.52	3.90	C _{14:0} Myristic	0.67 ± 0.14	
Leucine	3.92 ± 0.84	5.90	C _{16:0} Palmitic	7.11 ± 0.26	
Threonine	3.83 ± 0.34	2.30	C _{18:0} Stearic	2.51 ± 0.21	
Lysine	3.24 ± 0.28	4.50	C _{20:0} Arachidic	2.08 ± 0.11	
Isoleucine	3.15 ± 0.77	3.00	C _{22:0} Behenic	0.63 ± 0.16	
Tryptophan	2.40 ± 0.16	6.00	C _{24:0} Lignoceric	0.74 ± 0.19	
Methionine	1.33 ± 0.26	1.50	Total SFA	14.04 ± 0.19	21–34
Total Essential A. A	27.26 ± 0.25	27.70	C _{16:1} Palmitoleic	3.79 ± 0.12	
Arginine	9.44 ± 0.92	–	C _{18:1n9} Oleic	20.16 ± 0.31	
Histidine	2.01 ± 0.63	1.50	C _{20:1} Gadoleic	0.52 ± 0.22	
Total Semi-Essential A. A	11.45 ± 0.21		C _{22:1n-9} Erucic	0.82 ± 0.19	
Glutamic acid	19.82 ± 0.69		C _{24:1n-9} Nervonic	1.09 ± 0.15	
Aspartic acid	17.49 ± 0.15		MUFA	26.37 ± 0.20	24–39
Proline	7.27 ± 0.43		C _{18:2n6} Linoleic	56.57 ± 0.17	
Alanine	4.37 ± 0.17		C _{18:3n-3} Linolenic	0.59 ± 0.24	
Tyrosine	3.62 ± 0.12		C _{20:3n-6} Eicosatrienoic	2.43 ± 0.11	
Glycine	2.62 ± 0.83		PUFA	59.59 ± 0.17	11–17
Serine	2.39 ± 0.54		Total USFA	85.96 ± 0.19	
Cysteine	0.52 ± 0.72		USFA/SFA	6.12	
Total Non-essential A. A	57.10 ± 0.28				
Total A. A	95.81 ± 0.23	12.20			
First limiting amino acid	Lysine				
Second limiting amino acid	Methionine& Cysteine	2.20			

A.A: amino acids; DR: daily recommendations for adults by WHO/ FAO/UNU's 2007

Values are shown as the mean ± standard deviation, n = 3; SFA: saturated fatty acids; USFA: unsaturated fatty acids, MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

Table 4 Mineral composition of *P. pruinosa* fruit pulp.

Mineral	Content (mg 100 g ⁻¹)	DR (mg/kg/day)
Macro-minerals		
K Potassium	547.50 ± 0.23	4700
P Phosphorous	156.87 ± 0.19	700
Na Sodium	111.83 ± 0.11	1500
Mg Magnesium	32.66 ± 0.26	M: 400/ F:310
Ca Calcium	11.84 ± 0.31	1000
Micro-minerals		
Trace elements		
Fe Iron	2.06 ± 0.14	M: 9/ F:20
Zn Zinc	1.29 ± 0.22	M: 11/ F:8
Cu Copper	1.05 ± 0.16	0.9
Mn Manganese	0.41 ± 0.11	M: 2.3/ F:1.8
Co Cobalt	0.14 ± 0.24	1.5
Ultra-trace elements		
B Boron	0.06 ± 0.14	1–13
Cr Chromium	0.009 ± 0.11	M:0.04/ F:0.03
Cd Cadmium	0.005 ± 0.17	0.06

Values are shown as mean ± standard deviations, n = 3; M = meals; F = females.

DR: daily recommendations for adults by WHO/ FAO/UNU's 2004

jam, leather, candied fruit, and chocolate-coated dry fruit are shown in Table 6 and Fig. 4. The physicochemical properties included pH value, TSS (°Brix), titratable acidity (as citric acid

%), and TSS/acidity. There were no significant differences between the pH values of the different products and the original fruit. The chocolate-coated dry fruit, candied fruit, and leather fruit showed higher TSS values than other food products, and they were followed by jam and jelly. The addition of sugar leads to an increase in the TSS values. The titratable acidity was highest in leather compared with other products owing to the loss of moisture throughout dehydration procedure. The TSS/acidity was higher in jam and jelly than other products. The color properties of the fruit and prepared products were measured using the Lovibond test, and they showed that the highest values of blue, red, and yellow colors were found in the leather compared with other products, followed by jelly, jam, and candied fruit. The color coordinates can of course be changed due to different manufacturing processes and effect of heating. The crude fiber, total sugar content, reducing sugars, and non-reducing sugars of the food products were measured to indicate their nutritional properties. The highest crude fiber composition was found in chocolate-coated dry fruit, followed by leather, jam, candied fruit, and jelly. The highest total sugar content was found for chocolate-coated dry fruit (82.21%) and candied fruit (80.00%), followed by jelly, leather, and jam. The fructose and glucose contents were higher in jam (31.21% and 24.26%, respectively), jelly (29.11% and 23.12%, respectively), and leather (27.23% and 23.01%, respectively) than in other products. Additionally, the sucrose content was higher in chocolate-coated dry fruit and candied fruit compared with other products. The percentage of maltose was higher in juice, jelly, and leather than other products. The significant differ-

Table 5 Polyphenol profile of *P. pruinosa* fruit pulp (mg/100 g dry weight).

Compound pattern	Polyphenols	Mass Weight	Molecular Formula	RT (min)	Content
1	Gallic acid	170.12	C ₇ H ₆ O ₅	4.92	180.22
2	4-Aminobenzoic acid	137.14	C ₇ H ₇ NO ₂	6.77	4.89
3	Catechin	290.27	C ₁₅ H ₁₄ O ₆	8.86	10.43
4	Protocatechuic acid	154.12	C ₇ H ₆ O ₄	10.69	7.17
5	Naringenin	272.25	C ₁₅ H ₁₂ O ₅	14.85	30.82
6	Chlorogenic acid	354.31	C ₁₆ H ₁₈ O ₉	15.65	12.62
7	Catechol	142.18	C ₆ H ₆ O ₂	16.78	20.78
8	Epicatechin	290.27	C ₁₅ H ₁₄ O ₆	17.11	11.98
9	Caffeine	194.19	C ₈ H ₁₀ N ₄ O ₂	18.73	0.23
10	4-Hydroxybenzoic acid	138.12	C ₇ H ₆ O ₃	20.00	30.88
11	Caffeic acid	180.16	C ₉ H ₈ O ₄	21.03	8.92
12	Vanillic acid	168.15	C ₈ H ₈ O ₄	24.85	10.36
13	Syringic acid	198.17	C ₉ H ₁₀ O ₅	26.12	8.75
14	Vanillin	152.15	C ₈ H ₈ O ₃	29.00	2.32
15	o-Coumaric acid	164.158	C ₉ H ₈ O ₃	32.92	5.23
16	Ferulic acid	194.18	C ₁₀ H ₁₀ O ₄	33.45	4.48
17	Isoferulic acid	194.18	C ₁₀ H ₁₀ O ₄	35.21	5.74
18	Resveratrol	228.24	C ₁₄ H ₁₂ O ₃	36.43	2.82
19	Ellagic acid	302.19	C ₁₄ H ₆ O ₈	37.65	14.11
20	Benzoic acid	122.12	C ₇ H ₆ O ₂	38.65	24.85
21	3,4,5-trimethoxycinnamic acid	238.24	C ₁₂ H ₁₄ O ₅	39.42	1.51
22	Coumarin	146.14	C ₉ H ₆ O ₂	40.03	4.36
23	Salicylic acid	138.12	C ₇ H ₆ O ₃	41.86	8.38
24	Cinnamic	148.16	C ₉ H ₈ O ₂	45.61	2.73
25	Rutin	610.52	C ₂₇ H ₃₀ O ₁₆	63.14	14.02
26	Luteolin	286.24	C ₁₅ H ₁₀ O ₆	74.23	14.67
27	Kaempferol	286.24	C ₁₅ H ₁₀ O ₆	77.08	7.23
28	Quercetin	302.24	C ₁₅ H ₁₀ O ₇	79.05	8.71
29	Apigenin	270.24	C ₁₅ H ₁₀ O ₅	88.12	4.22

Rt: retention time in minutes, n = 3.

Polyphenolic compounds' molecular structures were obtained from <http://www.chemspider.com> database.

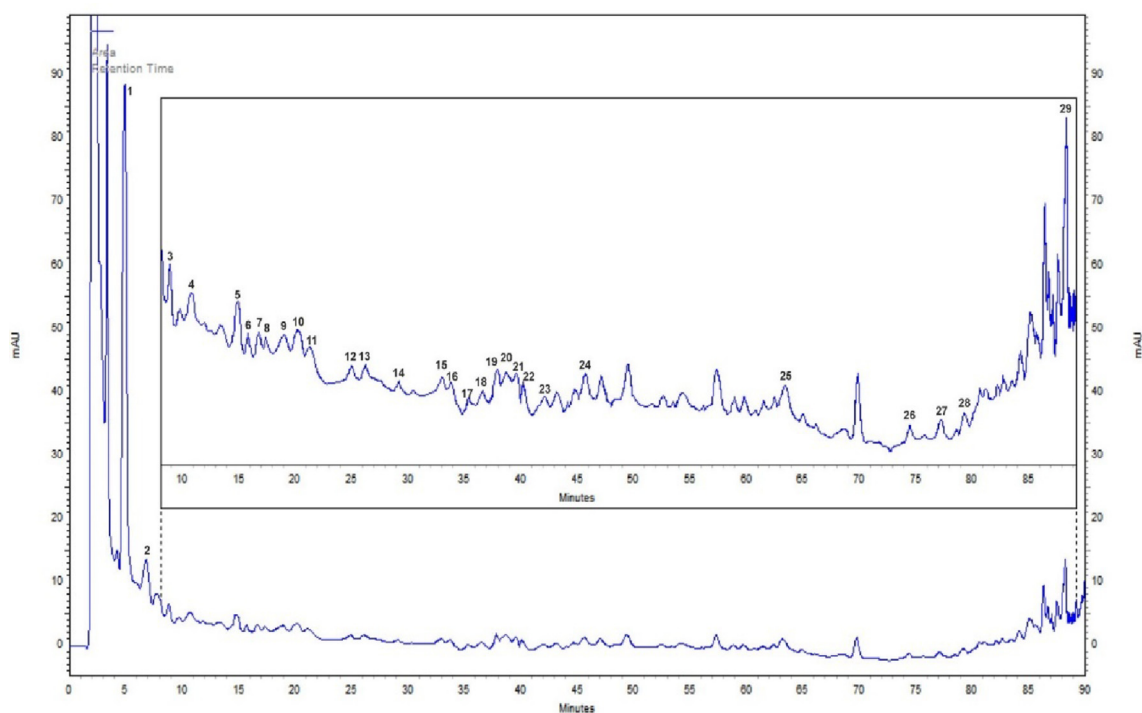


Fig. 3 Representative HPLC chromatogram of the methanolic extract of *P. pruinosa* fruit pulp.

Table 6 Physicochemical, color, and nutritional properties of prepared *P. pruinosa* food products.

Property	<i>P. pruinosa</i> Fruit	Prepared products					
		Juice	Jelly	Leather	Jam	Candied	Dry coated chocolate
Physicochemical properties							
pH value	3.80 ± 0.08 ^a	3.82 ± 0.11 ^a	3.62 ± 0.18 ^a	3.62 ± 0.19 ^a	3.70 ± 0.12 ^a	3.82 ± 0.18 ^a	3.37 ± 0.15 ^a
TSS (°Brix) *	12.85 ± 0.96 ^d	17.75 ± 0.52 ^c	67.85 ± 1.21 ^b	73.60 ± 1.42 ^a	66.85 ± 1.86 ^b	75.85 ± 1.34 ^a	76.34 ± 1.33 ^a
Titratable acidity (as citric acid %w/v)*	1.39 ± 0.28 ^b	1.51 ± 0.36 ^b	1.27 ± 0.42 ^b	4.78 ± 0.19 ^a	1.30 ± 0.12 ^b	1.76 ± 0.15 ^b	1.77 ± 0.25 ^b
TSS/Acidity	9.24 ± 0.63 ^d	11.75 ± 0.44 ^{cd}	53.43 ± 0.82 ^a	15.40 ± 0.81 ^c	51.42 ± 0.99 ^a	43.10 ± 0.75 ^b	43.13 ± 0.79 ^b
Lovibond Color properties							
Blue	1.36 ± 0.04 ^c	5.88 ± 1.12 ^b	5.57 ± 1.06 ^b	8.89 ± 0.09 ^a	5.59 ± 0.23 ^b	5.54 ± 0.78 ^b	0.94 ± 1.67 ^{cd}
Red	6.42 ± 0.03 ^c	8.27 ± 0.89 ^{bc}	9.96 ± 0.26 ^{ab}	11.82 ± 0.09 ^a	9.74 ± 0.45 ^{ab}	10.18 ± 0.29 ^{ab}	5.38 ± 1.02 ^{cd}
Yellow	21.46 ± 0.07 ^b	34.12 ± 0.34 ^a	21.78 ± 1.23 ^b	34.01 ± 1.16 ^a	23.01 ± 1.11 ^b	23.94 ± 0.78 ^b	12.63 ± 0.94 ^c
Nutritional properties							
Crude fiber (% w/w) **	11.59 ± 0.92 ^{bc}	10.37 ± 1.06 ^c	12.63 ± 0.49 ^b	13.40 ± 1.21 ^b	12.74 ± 0.56 ^b	13.25 ± 0.08 ^b	15.03 ± 0.67 ^a
Total sugar (%w/w) **	41.65 ± 0.85 ^c	22.53 ± 0.05 ^d	71.91 ± 1.06 ^b	78.83 ± 1.12 ^b	71.73 ± 0.08 ^b	80.00 ± 1.43 ^a	82.21 ± 1.21 ^a
Fructose (%of total sugar w/w) **	23.19 ± 0.19 ^b	22.06 ± 1.06 ^b	29.11 ± 0.07 ^a	27.23 ± 0.66 ^a	31.21 ± 1.23 ^a	21.98 ± 1.41 ^b	21.04 ± 0.57 ^b
Glucose (%of total sugar w/w) **	20.62 ± 0.11 ^b	19.45 ± 0.89 ^b	23.12 ± 0.65 ^a	23.01 ± 0.08 ^a	24.26 ± 1.21 ^a	18.82 ± 1.11 ^b	19.00 ± 0.62 ^b
Sucrose (%of total sugar w/w) **	52.83 ± 0.16 ^a	55.23 ± 1.23 ^a	44.64 ± 0.12 ^b	46.98 ± 0.09 ^b	42.53 ± 1.65 ^b	57.33 ± 1.11 ^a	58.12 ± 0.78 ^a
Maltose (%of total sugar w/w) **	3.36 ± 0.08 ^a	3.26 ± 0.09 ^a	3.13 ± 1.01 ^a	2.78 ± 0.06 ^a	2.00 ± 0.23 ^b	1.87 ± 1.01 ^b	1.84 ± 1.24 ^b
Ascorbic acid (mg/100 g) *	40.17 ± 0.53 ^a	17.14 ± 0.08 ^c	15.88 ± 1.02 ^c	15.19 ± 1.14 ^c	16.89 ± 0.78 ^c	29.78 ± 0.52 ^b	27.12 ± 0.06 ^b
β carotene (μg/g) *	64.78 ± 0.62 ^a	38.34 ± 0.44 ^d	47.88 ± 0.14 ^c	51.08 ± 0.58 ^{bc}	44.98 ± 0.08 ^c	54.58 ± 0.35 ^b	55.84 ± 0.12 ^b
Total tannins (mg tannic acid/100 g) **	36.65 ± 0.21 ^a	24.86 ± 1.12 ^c	30.96 ± 1.06 ^b	33.31 ± 0.78 ^b	32.26 ± 0.09 ^b	32.96 ± 0.46 ^b	33.12 ± 0.92 ^b
Total phenol content (mg gallic acid 100 g ⁻¹) *	32.44 ± 0.16 ^b	5.02 ± 2.63 ^c	9.48 ± 1.12 ^d	9.32 ± 0.63 ^d	10.56 ± 1.43 ^d	21.32 ± 1.34 ^c	165.44 ± 1.82 ^a
Total flavonoids (mg quercetin g ⁻¹) *	1.22 ± 0.32 ^b	0.59 ± 0.31 ^d	0.80 ± 0.22 ^c	0.78 ± 0.52 ^c	0.72 ± 0.55 ^c	0.92 ± 0.62 ^c	43.29 ± 0.82 ^a

Values = the mean ± standard deviation, n = 3. Means in a row that are not followed by the same letter are significantly different ($p \leq 0.5$). * on fresh weight basis and ** on dry weight basis.

ences ($p \leq 0.5$) in sugar content between the products was due to the percentage of added sucrose in each manufacturing process, as well as the inclusion of chocolate. Also, some bioactive compounds including ascorbic acid, β carotene contents, total tannins, total phenol content, and total flavonoids, of prepared *P. pruinosa* products were determined (Table 6). The antioxidants activity might be associated with the compositions of β-carotene, vitamin C, flavonoids, and the total phenols, because these compounds act as free radical scavengers formed during the oxidation reaction. The ascorbic acid composition was significantly higher ($p \leq 0.05$) in chocolate-coated dry fruit and candied fruit than other products. The β carotene composition was the highest in the fresh fruit, followed by chocolate-coated dry fruit and candied fruit products. Additionally, the total tannin content was higher in the fresh fruit than other products. The chocolate-coated dry fruit was high ($p \leq 0.05$) in total phenol (165.44 mg gallic acid 100 g⁻¹) and flavonoid contents (43.29 mg quercetin g⁻¹). This could be explained by the high polyphenols and flavonoids compositions in dark chocolate (Vertuani et al., 2014). In contrary, the

juice had lower amount of total phenol and flavonoid contents (5.02 mg gallic acid 100 g⁻¹, and 0.59 mg quercetin g⁻¹, respectively). A previous study on *P. pruinosa* fruit revealed higher values of total sugars (54.22%), titratable acidity (1.72%), ascorbic acid (178.88 mg/100 g), and comparable ash composition (5.98%) (Abou-Farrag et al., 2013) than our findings in this study. This previous study investigated the effect of drying methods on the drying behavior of the fruit. However, they did not investigate the possibility of obtaining products other than dried fruits products. The variations in some chemical compositions of the fruit of this species might be attributed to seasonal and environmental conditions. To the best of our knowledge, this is the first investigation on six food product processes from the fruit of *P. pruinosa*. Previous investigations on *P. peruviana* fruit revealed that their juice contained ascorbic acid at 51.8 mg 100 mL⁻¹, 4.97% crude fiber, a pH value of 3.6, and 11.3% of total sugar (Sharoba and Hassanien, 2010). In general, obtained data for manufactured products differ according to several factors such as the fruit species, processing procedure, temperature, and ingredients.



Fig. 4 New *P. pruinosa* manufactured products. (Photos by E. A. Mahmoud).

3.7. The sensory evaluation profile of prepared *P. Pruinosa* foodstuff

The sensory evaluation profile of the prepared products is shown in Fig. 5. In general, the 25 panelists accepted all of the prepared products. Our data showed that the jelly had the highest overall acceptability score from the panelists. With regard to the general acceptability of the product, there is no significant differences among the prepared products, while the fruit leather product had the lowest value. In terms of general appearance and color, there were no significant differences ($p \leq 0.05$) among fruit pulp (control sample), jelly, chocolate-coated dried fruits, candied fruits jam, and juice, while the fruit leather product received the lowest score. No significant difference in the odor and homogeneity values for the prepared products. The highest scores for odor were for the chocolate-coated dry fruit and jam products. However, the jelly and fruit leather showed the highest values for homogeneity. For taste attribute, the jelly, candied, jam, and chocolate-coated dried fruits were rated the highest. The candied fruit, jelly, chocolate-coated dry fruit, and, jam had the highest texture attribute values with non-significant differences. In previous research on *P. peruviana* fruit, several products had been produced, including compote, nectar, syrup, paste, jam and dehydrated fruits (Aamer, 2018), and there was no significant

difference in the general acceptability of the investigated products, while dehydrated fruits had lower value.

4. Conclusions

The current investigation sheds light mostly on the fruit of the *P. pruinosa*, which is already widely consumed fresh in most countries worldwide. There is strong evidence on the possibilities of developing six functional food products, such as jam, candied fruit, chocolate-coated dry fruit, juice, jelly, and fruit leather. *P. pruinosa* receive great attention for its good nutritional quality. The fruit contained high ratios of protein, total sugar, crude fiber, phenols, anthocyanin, flavonoids, and chlorophylls. High antioxidant activities were detected by the DPPH and ABTS assays. The major amino acids in the fruit pulp were glutamic acid, aspartic acid, arginine, phenylalanine, and alanine. The major polyphenols detected were gallic, p-OH-benzoic, benzoic, catechol, ellagic, chlorogenic, and epicatechin. Some flavonoids were available at high concentrations, such as naringenin, luteolin, and rutin. The fruit contained several minerals, including potassium, phosphorus, sodium, and magnesium. The physico-chemical, color, and nutritional properties of the fruit and prepared products were determined. The highest crude fiber, ascorbic acid, β carotene, tannins, polyphenol, flavonoids,

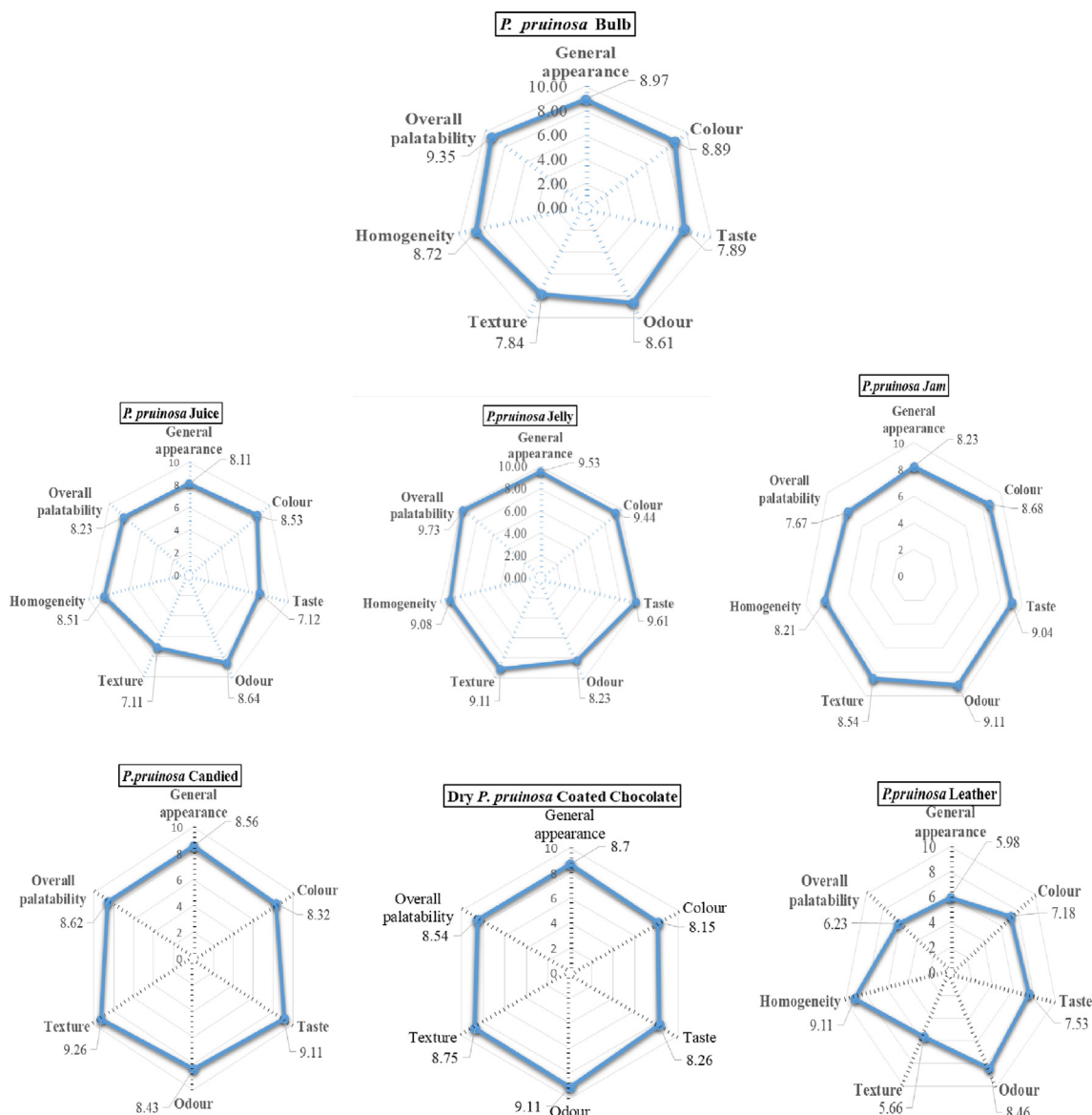


Fig. 5 Sensory evaluation profile of prepared husk berry foodstuff; Values = the mean \pm standard deviation, n = 20. Means in a column that are not followed by the same letter are significantly different ($p \leq 0.05$).

and total sugar contents were found in chocolate-coated dry fruit compared with other products. The sensory evaluation profile of the prepared products showed that all products were extremely acceptable based on its sensory attributes (general appearance, color, odor, texture, taste, homogeneity and overall palatability). Our findings suggest that, *P. pruinosa* fruit could be strong candidate for the processing of new functional foods and beverages for food industries. Future studies should be conducted on the antimicrobial activities, bioactive compounds, and texture properties of development functional products from *P. pruinosa* fruit in order to prolong the storage period.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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