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Review

Fruit-Based Leathers: A Comprehensive Review of Terminologies, Composition, and Quality Attributes

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Abstract: Fruit-based leathers were obtained from drying fruit purees, offering a high nutritional value and convenience in consumption, storage, and transportation. Challenges in advancing leather studies are being observed due to the various terminologies used to describe similar products. This review aims to systematically analyze the terminologies used in the literature and explore the effects of different ingredients on fruit-based leather development, focusing on bioactive compounds and sensory and texture properties. The Iramuteq® Software was utilized to categorize the most common terminologies. The review also examined the impact of ingredient incorporation, such as sugars and hydrocolloids, on fruit leathers' physical, chemical, and nutritional characteristics and their influence on sensory attributes and color. This comprehensive analysis provides valuable insights for future research in fruit-based leathers.

***Keywords*:** puree, snacks, quality attributes, bioactive compounds, sensory, texture, Iramuteq®

1. Introduction

Fruits and vegetables are considered important sources of dietary fiber and have relevant concentrations of vitamins, minerals, bioactive compounds, and antioxidants [1]. The Resolution implemented by the General Assembly on December 19th [2] declared that 2021 was the International Year of Fruits and Vegetables, considering the awareness of nutritional benefits. However, according to Food and Agriculture Organization of the United Nations (FAO) [3], the loss of fruits and vegetables in 2016 was the second largest (21.6%) concerning other foods, such as meats and animal products (11.90%), cereals and pulses (8.6%) and other (10.1%), behind only roots, tubers, and oil-bearing crops (25.3%). The fruit and vegetable losses along the food supply chain are due to the high perishability and seasonality that leads to unsaleable gluts [4]. There are several alternatives for greater utilization and reduction of losses of fruits, such as processing, obtaining juices and purees, or dried fruits [5]. Sustainable production and fruit and vegetable consumption are important and current factors for maintaining human health.

In the literature, products resulting from pulp dehydration and continuous film formation are referred to as leathers [6], fruit rolls [7], pestil [8], fruit bars [9], and edible films [10]. Fruit leathers are alternative products to fresh fruit consumption due to their high nutritional values [11]. According to Gómez-Pérez et al. [12], leathers are products from

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the restructuring of a fruit puree submitted to the drying process. After drying, flexible leaves of the fruit are obtained with a soft texture and shiny appearance, which due to these characteristics, are named leathers [13]. Dry leathers are usually rolled up and consumed as a snack [14] and can be stored in whole sheets or slices, rolled or not, and are easily transported [6].

Several studies in the literature have reported the production of fruit-based leathers using a single fruit such as grape [15], apricot [16], guava [17], apple [18], papaya [19], pineapple [11], pomegranate [20], peach [21], mango [22], mulberry [23] and soursop [24] or with two or more fruits such as banana, pineapple, and apple [25], apple or quince with maqui extract [26], apple with strawberry or kiwi [27], plum and ginger [28] and mustard greens with fruit purees (jackfruit, pineapple or papaya) [29].

The fruit leather production process is usually carried out the fruit processing, spreading, drying, and storage, whereas fruit processing involves the production of a puree. The fruit puree, pure or added with other ingredients, is evenly distributed with a predetermined thickness on support and followed by a drying process to reduce the moisture content.

The quality attributes of leathers are characterized based on several parameters such as water activity, soluble solids, acidity, pH and color [26], the proximal composition [27], the concentration of bioactive compounds, including phenolic compounds and anthocyanins [30], flavonoids, vitamin C and antioxidant activity [31], as well as the microstructure and texture [21] that can influence consumer choice and sensory acceptability [5], among others.

The effect of drying methods and conditions using different equipment to preserve the physicochemical and sensory characteristics of fruit leathers were reported in the literature, such as drying oven [32], refractance window drying [33], cast-tape drying [22], infrared drying, radio frequency dryer, and microwave-assisted hot-air drying [21], forced-air cabinet drying, electrohydrodynamic drying and freeze-drying [30], and tray drying with an in situ weighing system [13]. Different packaging and storage conditions are also evaluated to increase the shelf life of fruit leathers [34-35].

The fruit's composition and the incorporation of ingredients are important factors that can also affect the quality attributes of leather, influencing the nutritional and sensory value of the final product [36]. Incorporating components can improve fruit leathers' physical, chemical, and nutritional characteristics, providing higher concentrations of bioactive compounds and antioxidant activity [5, 26, 31]. The addition of sugars [35] or hydrocolloids [37] can improve or reduce texture properties, such as adhesion strength and extensibility, and influence sensory properties and coloring.

In this context, the objective of this review was to evaluate the main terminologies used to describe products based on fruit purees, to define the most common terminology to systematize studies in the area, as well as verify the effect of the ingredients used in the production of fruit-based leathers, in relation to bioactive compounds, sensory and texture properties. Studies that developed fruit leathers, fruit bars, pestil, and edible films were selected to be analyzed using the Iramuteq® Software to understand and evaluate the terminologies most used to describe products based on fruit purees.

2. Fruit leathers and other terminologies

Fresh fruits usually have high water activity, an average of 0.983 [38]. The fruit drying technique has been applied to reduce post-harvest losses and increase the consumption period [39]. The drying of fruit purees related to the production of leathers gained attention in the 1970s in North America, as it is a nutritious product, a source of fibers and natural sugars [40]. According to Moyls [41], fruit leathers are achieved by removing moisture from the fruit puree until the desired cohesive "leathery" composition is obtained, with a restructured conformation in a layer [12]. The fruit leathers can be considered snacks due to their practical consumption in quick meals [6].

Other terminologies have been used to designate the products with similar obtention processes used in leathers, making the progress assessment in the area difficult. The other terminologies found in the literature are pestil [15, 42-44], fruit bar [9, 45-46], and edible films [47-48]. Generally, the different terminologies found in the literature vary depending on the region of production/consumption and the formulation.

"Pestil" in Turkish is translated as "dried fruit pulp". Pestil is a product commonly produced in the Middle East [49]. Usually, they are obtained from puree or juice from plum, blackberry, apricot, fig, apple, and grape, and, when necessary, starch, sugar, and additives are incorporated, followed by drying, commonly carried out in the sun [50]. Other studies also report using starch or wheat flour in pestil production [15, 20, 43, 51]. According to Maskan et al. [15], the difference between pestil and fruit leathers is starch addition in pestil formulation.

Incorporating starch or flour is a differential, considering the ingredients added in the production process. However, this characteristic is not common in all studies. Sharma et al. [11] developed fruit leather-based on pineapple puree with the addition of starch. Simão et al. [22] did not consider the cassava starch addition in mango pulp leather development to define the product terminology. On the other hand, dried products based on papaya and tomato pulp with starch were called fruit bars [45]. Akhtar et al. [52] also developed a fruit bar based on pulp and apple with other ingredients, including starch. Local production can influence, as fruit bar is a terminology used mainly in India to denominate fruit-based puree products [9, 45].

The fruit bar processing is similar to leather, consisting of mixing the fruit pulp with sugar, followed by dehydration in a tray dryer, producing a texture similar to leather [53]. However, Tylewicz et al. [31] consider the drying technique as a differentiating factor between the products, as they classified freeze-dried products such as fruit bars and dried products in hot air dryers such as fruit leathers. However, hot air dryers were also used in other fruit bars development [11, 54-55].

Table 1. Physical-chemical parameters of fruit leather, pestil, fruit bar, and film

Product	Fruit	T (mm)	Aw	MC (g 100 g^{-1})	pH	Ref.
Leather	Mango	3.00	nd	10.00 (wb)	nd	[37]
	Pear	2.85*	0.360-0.480	6.42-13.47	nd	[61]
	Guava	1.40-2.40	nd	12.36-15.26 (wb)	nd	[62]
	Pineapple	2.00-2.10	0.395-0.546	6.40-10.30	3.60-3.80	[63]
	Apple	2.00*	nd	13.0 (dm)	nd	[64]
	Guava	6.00*	nd	17.87	3.92	[17]
	Apple and quince	8.00-10.00*	0.540-0.569	15.90-18.20	3.50-4.07	[26]
	Papaya	1.00	nd	14.31-15.42	3.82-3.93	[19]
	Rosehip	6.00*	nd	17.00-23.00 (dm)	nd	[65]
	Papaya and guava	3.00-6.00*	nd	16.43-16.47	3.80	[66]
	Mango	2.00	nd	14.08-22.40	3.48-3.56	[67]
	Persimmon	1.00-3.00*	nd	8.53-24.77	nd	[68]
	Mango	0.369-0.403	nd	5.70-6.80 (db)	nd	[22]
	Soursop	1.00	nd	11.49-15.50	4.04-5.41	[24]
	Hawthorn	2.0*	nd	9.14-11.89	nd	[69]
	Mango	9.00-10.00*	nd	32.02	nd	[32]
	Mango	3.00*	0.549-0.614	20.50 (wb)	nd	[33]

Table 1. (cont.)

Product	Fruit	T (mm)	Aw	MC (g 100 g^{-1})	pH	Ref.
Pestil	Pomegrate	1.50	0.566-0.553	10.00-12.00	3.6-3.7	[20]
	Pomegrate	0.89-1.46	nd	8.87-10.93	nd	[70]
	Pomegrate	1.00-3.00*	nd	12.40	nd	[49]
	Pomegrate	4.00*	0.586	13.75	nd	[71]
	Grape	0.71-2.86*	nd	11.00 (wb)	nd	[15]
	Grape	0.50-1.20	0.470	11.20	nd	[8]
	Grape	0.60	0.650	10.51 (db)	nd	[72]
	Beet	0.80-1.12	nd	9.78-10.75	nd	[73]
	Mulberry	nd	nd	13.12-14.39 (wb)	nd	[74]
	Apricot	0.90-1.12	nd	14.42-16.48	nd	[51]
Fruit bar	Guava	13.00*	nd	14.80	nd	[55]
	Papaya and tomato	nd	nd	20.90-22.30	nd	[45]
	Papaya	nd	nd	18.69	nd	[54]
	Apricot	4.00-5.00*	nd	18.89	nd	[16]
	Apple and date	nd	nd	27.9-30.14 (wb)	5.3-5.4	[52]
	Sapodilla	5.00-8.00*	0.744-0.802	18.70-20.20	nd	[75]
	Mango	nd	nd	16.54-17.26	nd	[9]
	Apricot	3.00*	nd	12.44-13.18	nd	[69]
Edible film	Acerola	1.20*	nd	nd	nd	[56]
	Açaí	0.18	nd	nd	nd	[59]
	Papaya	0.12-0.12	nd	nd	nd	[76]
	Peach palm-tucupi	0.20-0.21	0.250	6.44-8.44 (db)	nd	[10]
	Mango and guava	0.10	nd	nd	nd	[77]
	Squash	nd	0.270	14.53	nd	[78]

Note: Aw = water activity; MC = moisture content; nd = not determined; T = thickness; db = dry basis; dm = dry matter; wb = wet basis * = spreading thickness

The edible films can also be produced based on fruit puree, incorporating polysaccharides, proteins, lipids, and, when necessary, plasticizers and surfactants to improve structural and barrier properties [48, 56-57]. Films or edible coatings are an alternative to reduce environmental impacts caused by petroleum-derived polymers [58]. Films or edible coatings are usually produced with biodegradable materials and can be used as food packaging [59-60]. At the same time, leathers are intended exclusively for food and are considered healthy snacks with high nutritional value [36]. Therefore, these products have some particularities, as seen in Table 1.

Edible films generally have a lower thickness (T) and Aw (0.15 ± 0.05 mm and 0.250 ± 0.014, respectively) when compared to leathers (1.68 ± 0.83 mm and 0.538 ± 0.074) and pestil (1.02 ± 0.30 mm and 0.567 ± 0.075). Some studies reported only the spreading thickness, spreading thickness being greater with fruit bar (6.75 ± 4.41 mm), followed by leathers (4.68 ± 2.85 mm) and pestil (2.59 ± 1.22 mm).

Fruit bars showed higher moisture content (MC) and pH (19.81 ± 4.80 g 100 g^{-1} and 4.43 ± 1.29, respectively), followed by leathers (15.05 ± 5.85 g 100 g^{-1} and 3.90 ± 0.38), pestil (11.87 ± 1.88 g 100 g^{-1} and pH 3.65 ± 0.07) and edible films (10.98 ± 5.01 g 100 g^{-1}). Within the consulted literature, the films' spreading thickness and pH were not reported. It was also observed that some authors used the two terms leathers and pestil in the same study to denominate these products based on fruit puree, such as Tontul and Topuz [20], Yilmaz et al. [50] and Kaya and Kahyaoglu [72].

There is no established standard for this type of product in the literature. As it is a fruit-based product, its composition may vary due to adding fruits, the climatic conditions of each region, soil type, fruit cultivation techniques, and the raw materials processing. Many techniques are used for drying this product, which can also influence its composition, not just the formulation itself.

3. Data analysis

Data analysis was performed using the free software Iramuteq® (Interface R pour read Multidimensionnelles de Textes et de Questionnaires), developed by Pierre Ratinaud and licensed by the GNU GPL, anchored in the statistical software R and based on the Python language [79]. Iramuteq has a set of processing and tools to assist in the description and statistical analysis of corpus and textual matrices [80].

According to Camargo and Justo [81], the Iramuteq® software allows the performance of different types of analysis of textual data, from simple, such as word frequency calculation, to multivariate analysis, such as Descending Hierarchical Classification (DHC), correspondence analysis, and similarity analysis. The software itself organizes visually the distribution of vocabulary through graphical representations based on the analysis used [79].

To understand and evaluate the terminology used to denominate products based on fruit purees, 88 studies were selected, including scientific articles and reviews published from 1978 to 2020 on fruit leathers, fruit bars, pestil, and edible films, and a textual corpus was created containing titles, abstracts, and keywords of the studies that addressed the research question.

The texts of scientific articles were generally composed of numerical data, measurement units, and symbols. These were eliminated for the textual analysis since the analysis of these characters was not of interest, as proposed by Ratinaud and Marchand [80]. The textual corpus was revised and formatted according to Loubère and Ratinaud [79] and Camargo and Justo [82]. After formatting and performing the statistical analysis by the software, the corpus composed of 88 texts presented several occurrences (total number of words contained in the corpus) of 15,421.0, number of forms (number of active and supplementary words) of 1,743.0 and number of hapax (words that appeared only once) of 724.0 where 4.69% and 41.54% corresponded to the number of occurrences and forms, respectively.

The DHC proposed by Reinert [83] allows for obtaining classes of text segments that present similar vocabulary and are different from other segments of other classes. Figure 1 shows a dendrogram created by the software, which organizes and illustrates class relationships.

Figure 1 represents the interactions performed in the classification of text segments and the size of the classes expressed in the percentage of the textual corpus. According to the DHC analysis, 5 classes were obtained, with their respective percentages in relation to the textual corpus. Thus, the corpus was divided into two subcorpus, separating class 5 (1st partition) from the rest. A larger subcorpus was divided, giving rise to class 3 (2nd partition), and a new division gave rise to class 2 (3rd partition), and finally, the separation of classes 1 and 4 (4th partition). The 5 classes are composed of units of text segments with similar vocabulary, and note that the number of partitions corresponds to the number of classes minus one [82]. Figure 2 presents the correspondence analysis between words belonging to the same lexical field whose colors correspond to the classes presented in the dendrogram (Figure 1). The text size is proportional to the frequency of the word cited in the textual corpus.

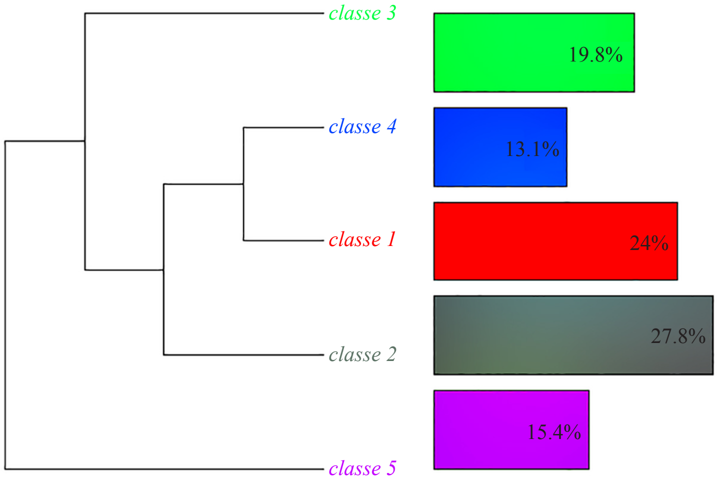

Figure 1. Dendrogram resulting from the DHC

Leather appeared more prominent between factors 1 and 4 (Figure 2), representing the most cited word within the textual corpus in classes 1 (in red) and 2 (in gray). Fruit bars also appeared in class 1 and pestil in class 2, indicating that these products resemble leathers and belong to the same lexical group. In classes 1 and 2, still appeared the words fruit, pulp, variety, antioxidant activity, bioactive, phenolic, color, pH, soluble solids, organoleptic, flavor, fiber, sugar, and ascorbic acid, among others.

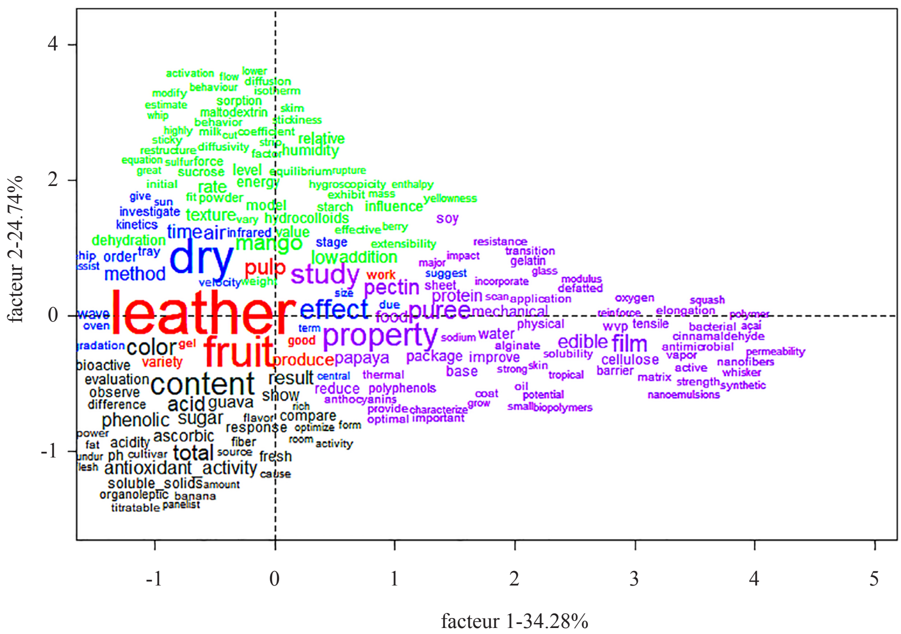

Figure 2. Correspondence analysis and lexical fields

Pestil also appeared in class 4 (in blue), along with dry, temperature, effect, method, and time, indicating that studies that developed pestil mainly investigated the drying process, including different drying methods (Figure 2). It can also be observed that studies on edible films (class 5, in purple) are opposed to other products (leathers, pestil, and fruit bar) and shows the relationship between the property, of edible films and water, with mechanical and barrier properties, such as WVP (water vapor permeability) that is usually evaluated in films, and which are characteristics related to the properties of edible and/or biodegradable packaging.

4. Fruit leather

4.1 *Composition of leathers*

The composition of fruits is a determining factor for the quality of leather, associated with the ingredients added in the formulation, which can alter the nutritional and structural characteristics of the final product [36]. The ingredients used to produce leathers are variable and can include sugars [13], hydrocolloids [37], acids [29], antioxidants [37], and preservatives [84]. The addition of sugars mainly affects the organoleptic characteristics and the flavor of the products, while the addition of hydrocolloids mainly influences the texture. The addition of acids, preservatives, and antioxidants has a more significant influence on preserving bioactive compounds and antioxidants. Table 2 presents the influence of adding ingredients on the final characteristics of fruit leathers. Apple, mango, and papaya are fruits generally used to produce leather (Table 2).

The mixture of fruit purees for developing leathers contributes to improving nutritional quality and may reflect in the reduction of post-harvest losses [66]. Offia-Olua and Ekwunife [25] reported higher banana content (60%), higher fiber content, and vitamin C in leathers containing bananas, pineapple, and apples. Adding jackfruit puree to leathers based on mustard leaves increased the content of crude fiber from 0.68% to 1.45% [29].

The added fruits' intrinsic characteristics (acidity, color, among others) can promote desirable sensory properties to the leather, such as acidity, color, and flavor, without adding additives [28]. Mango leathers without preservatives and sugars reduced the water activity and pH and promoted microbiological stability (total and fecal coliforms, *Escherichia coli*, counts of total mold and yeasts, mesophilic aerobes, and *Salmonella* sp.) for up to 6 months at 25 °C storage [14].

The sweetness in fruits is provided by natural sugars, such as fructose, inverted sugar, sucrose, and glucose [92]. The incorporation of sugars in fruit leathers is generally reported by several authors [63, 85, 93], and it is associated with an increase in the content of total soluble solids and sweetness [25] and also can influence the texture [63] and drying time [86].

The addition of corn syrup softened, decreased springiness, and increased the adhesiveness of fruit leathers [61]. A reduction in adhesion force and a degree of cohesive failure were observed by adding maltodextrin to apple leathers, while adding glucose increased adhesion force [18].

The formation of sugar crystals on the surface was observed in rosehip leathers, which was associated with the high content of soluble solids combined with the hot airflow-dried, allowing the formation of crystals and making the surface rougher [7]. Gujral et al. [87] evaluated the effect of adding sucrose, pectin, and maltodextrin to the moisture diffusion of pineapple and mango leathers and observed a reduction in the drying rate when the three ingredients were added at maximum concentrations (10% sucrose, 2% pectin, and 5% maltodextrin). This was associated with the increase in total soluble solids and water molecule bonds. The pineapple leathers with maximum concentrations of glucose syrup (6%) and minimum pectin (0.5-1%) were more sensorial accepted since the judges preferred softer, moist, and sweeter leathers [63].

In many cases, hydrocolloids are incorporated to form a continuous and cohesive structure characteristic of leather. Among the hydrocolloids used in the leathers' formulations (Table 2), it was found: Arabic gum, guar gum, gum acacia, carrageenan, carboxymethylcellulose, sodium alginate, soy protein, starch, gelatin, pectin, varying in different concentrations (0.25-9.00%), in which pectin is the most widespread. The mango leather texture was improved by adding gum arabic, maltodextrin, pectin, and carboxymethylcellulose [67]. The same behavior was observed with the addition of pectin in leathers using concentrated pear juice, and in a lower concentration of pectin (16%) resulted in the formation of soft and consumer-attractive leathers [61].

Table 2. Influence of fruit leather composition on nutritional, sensory, and texture properties

Composition	Effects	Ref.
Kiwifruit puree, glucose syrup (10-20%), water (10%), sugar (6%), pectin (1-3% w/w), salt (0.5%) and citric acid (0.2%)	↑ tensile strength, moisture content and preference (15% of glucose syrup and 2% of pectin)	[85]
Pineapple puree, pectin (0.5-1.5%), glucose (2-6%), sugar (12%) and maltodextrin (2%)	↑ redness, yellowness, and hardness ↓ moisture content and water activity	[63]
Data (100 g), tamarind (100 g), 200 g of water, hydrocolloids (0-3 g 100 g^{-1} puree of starch corn, pectin, maltodextrin, or guar gum)	↑ hardness, gumminess, and chewiness (except maltodextrin) ↓ cohesiveness, resilience and springiness	[86]
Pineapple pulp or mango pulp, sucrose (0-10%), pectin (0-2%) and maltodextrin (0-5%)	↓ drying rate ↑ effect of pectin on moisture diffusivity	[87]
Canned apple puree and gelatin (0-1.5% w/w)	↑ time the gas hold-up ↓ bubble size of the foam, time of drying and mechanical properties	[64]
Apple juice concentrate (20-40%), blackcurrant concentrate (3-9%) and pectin (0-4%)	↑ moisture content, water activity and ascorbic acid ↓ chroma and puncturing force	[5]
Banana: pineapple: apple (ratios 60:20:20, 40:40:20 and 20:40:40 w/w) and sugar solution (65%)	↑ vitamin C and fibre content (banana: pineapple: apple 60:20:20 w/w)	[25]
Canned apple puree and maltodextrin (0-10%)	↑ rugosity ↓ adhesion force and cohesive failure with 10% of maltodextrin in RH 33%	[18]
Canned apple puree and maltodextrin (0-15%)	↓ hygroscopicity ↑ puncture force, puncture deformation, maximum amplitude, and crispness	[35]
Apple our quince, water (150 mL or 250 mL) and maqui extract (0-1,8 g 100 g^{-1} of fruit)	↑ browning index, total phenolics, antioxidant activity, storage ability and functional ↓ overall acceptance	[26]
Ginger (50%), plum (50%) and appetizing mixture (0-1.5% with thyme seed powder, mint powder, salt, and black salt)	↑ ascorbic acid, total phenol, and antioxidant activity	[28]
Apple (78%), black currant (16.5%), sugar (5.5%), raspberry press cake powder (0-1%) or black currant press cake powder (0-2%)	↓ firmness ↑ content of anthocyanins and antioxidant capacity	[88]
Soursop pulp (60-100% w/w), oats flour (0-40% w/w), pectin, citric acid, and glucose syrup	↓ drying time and hardness ↑ protein content, minerals content and preference (soursop: oats flour 60: 40 w/w)	[24]
Apple (220 g), probiotics agavins and inulin (0-6%) in aqueous solution (50 mL citric acid 1%)	↑ compacted matrices, with agavins smoother and acceptability ↓ porous and hardness with agavins	[89]
Murta and gelatin (0-1%), potato starch (0-4%), or carrageenan (0-0.2%)	↑ drying kinetics and activation energy, except with gelatin ↓ diffusion coefficient, except with gelatin ↓ hardness, gumminess, and chewiness with gelatin	[12]
Peach pulp (0-100%) and hydroxypropyl methylcellulose (0-20%)	↓ resistance and stiffness ↑ extensibility, permeability to moisture and plasticizer effect of the pulp	[90]
Mustard greens: fruit purees (jackfruit, pineapple, or papaya) ratios 100:0, 40:60, 60:40 and 80:20 (w/w), sugar (20%), carrageenan (1%) and citric acid (0.2%)	↑ crude fiber content and hardness ↓ moisture content ↑ overall acceptance mustard greens with pineapple (60:40 w/w)	[29]
Pomegranate juice concentrate (80%), honey (10%), skimmed milk powder (10%), starch (10%), locust bean gum (0-7.5%) and pregelatinized starch (0-2.5%)	↑ moisture content, total monomeric anthocyanin, total flavonoid, and antioxidant activity	[70]
Kundur and pineapple (ratio 80: 20, 70:30, 60: 40 w/w) and sugar (20-40%)	↑ quality and fiber content: kundur: pineapple (80: 20 w/w) ↓ moisture content	[91]

Note: Tg = glass transition temperature; RH = relative humidity

The addition of guar gum and pectin in mango leathers did not affect the color parameters and drying time, despite modifying the texture [37]. Gómez-Pérez et al. [12] reported that not only the temperature (50-70 °C) but also the type of hydrocolloid influenced the drying of myrtle leathers, except for leathers with the addition of 1% gelatin, which drying kinetics was similar to the sample without hydrocolloid for the three temperatures evaluated. Also, according to the authors, gelatin leathers (1%) showed less resistance to deformation, hardness, and gumminess in relation to the other hydrocolloids (starch and carrageenan). Gelatin was used as a foaming agent in apple leathers, verifying a reduction in mechanical properties (force of rupture, modulus of deformation, and energy of rupture) based on the addition of gelatin (1-1.5%) and whipping time (3-9 min) [64].

The addition of ingredients can generally change the leather's texture, color, sweetness, acidity, and nutritional value properties (Table 2). The ingredients can also influence the glass transition temperature (Tg), altering the texture properties. A strong correlation between Tg, hardness, chewability, and sensory attributes was observed in the leathers of pear juice concentrate softened at temperatures above Tg, and the addition of corn syrup also contributed to softening and reduced springiness and, consequently, increased adhesiveness [61].

Acids in foods influence nutritional value and palatability, improving the taste, and shine and increasing stability and consistency [25]. Ascorbic acid [67] and citric acid [24] have been added to the formulation of fruit leathers to increase stability and prevent browning. The addition of acids through fruit juices (pineapple or lemon) can contribute to preventing the browning of leather [6].

The acids in the leather formulation can reduce the degradation of bioactive compounds due to thermal processes. The synergism of ascorbic acid and citric acid can compensate for the loss of total phenolic compounds due to the pasteurization process that preceded the drying of mango leather [67]. Adding citric acid to papaya leathers increased the acidity and the sensory acceptable [66]. It was necessary to add citric acid to papaya leathers to protect the natural color of the pulp, and it also contributed to inhibiting bacteria during the drying process [19].

Potassium metabisulfite ($K_2S_2O_5$) is a common preservative used in the composition of leathers. $K_2S_2O_5$ is derived from sulfur dioxide (SO_2) and is considered a sulfiding agent with good stability against self-oxidation in the solid phase [94]. These additives are added to foods to inhibit non-enzymatic browning, reactions catalyzed by enzymes, control microbial growth, and act as an antioxidant [94]. Generally, $K_2S_2O_5$ is added to leather fruits with a high oxidation index. A greater retention of antioxidant capacity of apple leathers with the potassium metabisulphite addition was observed compared to control leathers without the additive [13]. Apple leathers with the potassium metabisulphite had a lower browning index and less reduction in antioxidant activity (15.9%) compared to the control (47%). They did not show microbial growth during 7 months of storage at 20 °C [7]. The potassium metabisulphite was also added in the preparation of guava [17], guava and papaya [95], and mango [33] leathers.

4.2 *Characterization of leathers*

4.2.1 *Bioactive compounds*

The bioactive compounds and antioxidants in fruits offer several benefits to human health and basic nutritional functions. Some of the main benefits are combating free radicals present in the body, reducing oxidative stress, improving cardiovascular health due to its anti-inflammatory and antihypertensive properties, strengthening the immune system, improving gastrointestinal health, and controlling body weight, among others [96-98].

In the literature, the consumption of fruit leathers is associated with the ingestion of bioactive compounds with antioxidant activity [49, 99] and vitamins [31, 66]. Combining two or more fruits has been investigated to improve the nutritional value of leathers based on the concentration of bioactive compounds and antioxidants [25-26, 99].

There is significant variability in relation to the concentration of bioactive compounds, as expected, depending on the composition of these products, the type of fruit, drying conditions, and storage, among other parameters. The most bioactive compounds in fruit-based leathers reported are total phenolics, total flavonoids, ascorbic acid content, and the determination of antioxidant activity (Table 3).

The drying process is the most critical step in the leather production process, as it can lead to the degradation of compounds. Leathers have considerable concentrations of active compounds and, consequently, antioxidant activity, as seen in Table 3. The purpose of leather production is to preserve the nutritional value of fresh fruits and maintain their health benefits. Thus, the drying process must be harmful, ensuring the preservation of nutritional components.

The concentrations of bioactive compounds and antioxidants were analyzed in fruit and fruit leathers, verifying the increase of these compounds after drying. Torres et al. [26] reported that the quince puree and apple puree with maqui after cooking, showed higher total phenolics content and antioxidant capacity than fresh fruit. This fact can be attributed to the products of the Maillard reaction (melanoidins and reductones) and polyphenols hydrolysis products. However, these compounds decreased after drying the leather [26].

Table 3. Content of total phenolic, total flavonoids, total carotenoids, total anthocyanins, ascorbic acid, and antioxidant capacity of fruit leathers

Fruit leathers	Total phenolic	Total flavonoids	Total carotenoids	Total anthocyanins	Ascorbic acid	Antioxidant capacity	Ref.
Guava	nd	nd	nd	nd	78.46 (mg 100 g^{-1})	nd	[17]
Banana, pineapple, and apple	nd	nd	nd	nd	17.53-22.33 (mg 100 g^{-1})	nd	[25]
Papaya	104.71-121.40 (mg GAE 100 g^{-1} dw)	91.43-108.78 (mg QE 100 g^{-1} dw)	nd	nd	nd	84.97-92.12 (%)^{a*} 76.11-89.47 (%)^{b*} 231.51-284.32 (mg TE 100 g^{-1} dw)^{c*} 29.54-34.40 (µmol TE g^{-1} dw)^{d*}	[19]
Apple and strawberry	~160 (mg CAE 100 g^{-1} dw)	nd	nd	nd	nd	~180 (mg CAE 100 g^{-1} dw)^{b*} ~2900 (µmol TE 100 g^{-1} dw)^{d*}	[27]
Apple and kiwi	~75 (mg CAE 100 g^{-1} dw)	nd	nd	nd	nd	~130 (mg CAE 100 g^{-1} dw)^{b*} ~2,000 (µmol TE 100 g^{-1} dw)^{d*}	[27]
Pineapple	22-50 (mg GAE g^{-1})	11.11-71.43 (mg QE 100 g^{-1})	nd	nd	16.23-45.84 (mg 100 g^{-1})	69.81-99.90 (%)^{b*}	[11]
Ginger and plum	53.54-55.89 (mg 100 g^{-1})	nd	nd	nd	12.05-13.16 (mg 100 g^{-1})	72.61-72.94 (%)^{b*}	[28]
Pomegranate	852.36-1327.02 (mg GAE 100 g^{-1} db)	96.72-123.81 (mg CE 100 g^{-1} db)	nd	5.90-18.50 (mg C3G 100 g^{-1} db)	143.63-267.88 (mg 100 g^{-1} db)	1.82-2.42 (g TE 100 g^{-1} db)^{b*} 5.51-9.30 (mM TE 100 g^{-1} db)^{d*}	[20]
Pomegranate	1088.73-1268.67 (mg GAE 100 g^{-1} db)	112.55-126.88 (mg CE 100 g^{-1} db)		7.94-11.26 (mg C3G 100 g^{-1} db)	nd	1.84-2.12 (g TE 100 g^{-1} db)^{b*}	[70]
Apple with blackcurrant and raspberry	949.36-1001.98 (mg 100 g^{-1} dw)	nd	nd	74.10-156.37 (mg C3G 100 g^{-1} dw)	nd	72.9-80.0 (µmol TE g^{-1} dw)^{a*} 19.0-21.3 (µmol TE g^{-1} dw)^{b*} 33.3-38.0 (µmol TE g^{-1} dw)^{d*}	[88]
Blueberry	18.40-25.70 (mg GAE g^{-1} dm)	nd	nd	5.14-6.76 (mg C3G g^{-1} dm)	nd	59.19-73.38 (µmol TE g^{-1} dm)^{b*}	[30]
Mango	455.7-1453.5 (mg GAE 100 g^{-1} fl)	nd	nd	nd	nd	12.4-17.0 (mM TE 100 g^{-1} fl)^{a*} 13.8-18.6 (mM TE 100 g^{-1} fl)^{b*}	[67]
Pomegranate	1134.30 (mg GAE 100 g^{-1} db)	147.88 (mg CE 100 g^{-1} db)	nd	18.62 (mg C3G 100 g^{-1} db)	124.73 (mg 100 g^{-1} db)	3.00 (g TE 100 g^{-1} db)^{b*} 9.71 (mM TE 100 g^{-1} db)^{d*}	[71]
Mango	nd	nd	35.40-36.67 (µg g^{-1} db)	nd	nd	nd	[22]
Olive	203.10 (mg GAE 100 g^{-1})	55.90 (mg QE 100 g^{-1})	nd	nd	29.70 (mg 100 g^{-1})	77.30 (%)^{b*}	[100]

Table 3. (cont.)

Fruit leathers	Total phenolic	Total flavonoids	Total carotenoids	Total anthocyanins	Ascorbic acid	Antioxidant capacity	Ref.
Hawthorn	3,997.13-4,295.27 (mg GAE kg^{-1} db)	11,210.69-1,231.61 (mg CE kg^{-1} db)	nd	nd	236.78-279.72 (mg kg^{-1} db)	3,151.54-3,269.76 (mg TE kg^{-1} db)[b*] 13,128.52-15,130.14 (mg TE kg^{-1} db)[c*]	[69]
Soursop	355.38-365.86 (mg GAE 100 mg^{-1})	nd	nd	nd	6.33-6.54 (mg 100 g^{-1})	nd	[101]
Mango and plum	~100-850 (mg GAE 100 g^{-1})	nd	nd	nd	nd	~110-260 (mg AAE g^{-1})[d*]	[32]
Mango	nd	nd	12.2 (%)	nd	55 (mg 100 g^{-1})	nd	[102]
Guava and papaya	nd	nd	0-1,600.2 (µg 100 g^{-1})	nd	43.80-226.60 (mg 100 g^{-1})	nd	[95]
Kiwifruit and strawberry, spinach or lemon	~950-1,300 (mg GAE 100 g^{-1} dm)	~0.45-3.50 (mg QE 100 g^{-1} dm)	nd	nd	~5-13 (mg 100 g^{-1} dm)	~0.05-0.88 (mg dm mL^{-1})[a**]	[31]
Açaí and banana	125.22-166.01 (mg GAE g^{-1})	nd	nd	nd	6.65-11.91 (mg 100 g^{-1})	9.10-9.59 (µM TE g^{-1})[a*] 10.31-13.60 (µM FS g^{-1})[c*]	[99]

Note: [a*]ABTS = radical cation (2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid); [a**] = concentration of extract from dried material required to reduce 50% of ABTS radicals (EC_{50} ABTS); [b*]DPPH = radical scavenging activity; [c*]FRAP = ferric reducing antioxidant power; [d*]ORAC = oxygen radical absorbance capacity; AAE = ascorbic acid equivalent; CAE = chlorogenic acid equivalent; CE = catechin equivalent; C3G = cyaniding-3-O-glucoside; FS = ferrous sulfate; GAE = gallic acid equivalent; QE = quercetin equivalent; TE = trolox equivalent; db = dry basis; dm = dry matter; dw = dry weight; fl = fresh leather; nd = not determined.

The drying process increased the amount of ascorbic acid in *açaí* leathers with banana and different hydrocolloids (agar-agar and gellan gum) in relation to the formulations before drying (4.50-6.65 mg 100 g^{-1}) since concentrated the solid components after the water removal [99]. Regarding the concentration of total phenolic compounds, there was a significant reduction after drying (Table 3), this variation was 201.78-227.96 mg GAE g^{-1} [99].

The fresh pineapple pulp showed 22.5 mg GAE g^{-1} of total phenolic compounds, 76.97 mg QE 100 g^{-1} of flavonoids, 74.54 mg 100 g^{-1} of ascorbic acid and antioxidant activity of 64.31% (in terms of DPPH scavenging). After the extrusion process, active compounds were reduced, and increased antioxidant activity (Table 3). This effect was associated with releasing cellular components from the matrix (pulp) from the breakdown of cells during cooking, in addition to the formation of pigments resulting from the Maillard reaction [16]. Concha-Meyer et al. [27] attributed the Maillard reaction to increased phenolic compounds and antioxidant activity of apple and strawberry leathers over 28 days of storage under accelerated conditions.

The variation in relation to the concentration of bioactive compounds and antioxidants is due to the different formulations and drying methods, and temperatures investigated (Table 3). Singh et al. [95] reported a concentration of ascorbic acid of 43.8 mg 100 g^{-1} and total carotenoids of 1,600 µg 100 g^{-1} for guava:papaya 0:100 (w/w) formulation, and the concentrations of ascorbic acid was 226.6 mg 100 g^{-1}, varying to 100:0 (guava: papaya w/w, and did not show higher total carotenoids.

The ascorbic acid content in five guava cultivars ranged from 165.41 to 261.00 mg 100 g^{-1}, and after the leather production, the variation ranged from 94.64 to 215.04 mg 100 g^{-1} [62]. Vasanthakaalam et al. [66] found a decrease of vitamin C of approximately 6.7% and 11.3% in papaya and guava purees in relation to leathers, respectively. The antioxidant activity of bioactive compounds could protect against free radicals and prevent diseases related to oxidative stress, such as cognitive ability and the health of the cardiovascular, eye, bone, and joints [103].

The most widely used methods to determine the antioxidant capacity of fruit leathers in the literature were ABTS, DPPH, FRAP, and ORAC (Table 3). Among the vitamins, ascorbic acid or vitamin C was the most investigated in fruit leathers. Citrus fruits, such as oranges, lemons, and tangerines, among others, are considered sources of vitamin C [92].

However, tropical and subtropical fruits, available throughout the year, can also be considered alternative sources of vitamin C in the diet, among avocado, pineapple, papaya, mango, banana, and pomegranate [92]. Leathers containing 60% banana, 20% pineapple, and 20% apple presented higher vitamin C content (22.33 mg 100 g^{-1}) than the other formulations evaluated with different proportions of these fruits [25].

The sugar addition may have been responsible for reducing the ascorbic acid content in guava leathers of different varieties, with a relationship observed between the reduction in ascorbic acid content and increasing the sugar content [62]. The same was observed in kiwifruit and strawberry leathers, spinach, or lemon juice with sucrose or trehalose addition [31].

Fruit leathers, with the addition of other ingredients as a source of bioactive compounds and antioxidants, were found in the literature. Mango leathers, incorporating native plum (2:1, w/w), increase the content of bioactive compounds [32]. An increase in the content of phenolic compounds and antioxidant activity in apple and quince leathers enriched with lyophilized maqui extract was verified [26]. The bioactive compound content was influenced by the leather's composition and the drying method [31] (Table 3).

The blackcurrant concentrate increased the ascorbic acid content of apple juice concentrate leathers by up to 10.69% in relation to apple pulp [5]. The blackcurrant press cake powder addition to apple leathers promoted a significant increase in the content of anthocyanins, phenolic compounds, and antioxidant activity (ABTS, DPPH, and FRAP), compared to leathers added with raspberry press cake powder or control [88].

Fruit variety can affect the content of bioactive compounds and antioxidant activity of the leathers, as two varieties of hawthorn leathers (*Crataegus orientalis* var *orientalis*), colored yellow and orange, presented a higher content of total phenolic compounds, total flavonoids, and antioxidant activity in leathers produced with the orange variety, except for the ascorbic acid content [69].

The effect of storage conditions on the content of bioactive compounds [17, 28, 95] was investigated. A reduction in total phenolic compounds content (~260 GAE 100 g^{-1} dry matter) was observed during the preparation of the formulation of kiwi leathers with apple. However, there was an increase in this content (563.93 GAE 100 g^{-1} dry matter) in the final product, attributed to the concentration of compounds due to water loss. There were no differences in the antioxidant activity of apple leathers after 27 days of storage, and this stability was attributed to polyethylene packaging [104]. Guava leathers with papaya packed in biaxially oriented polypropylene showed higher nutrient retention (ascorbic acid and carotenoids) than leathers packed in punnets over 4 months of storage [93].

Ascorbic acid (34.6%) and phenolic compounds (3.22%) contents of the soursop leathers were reduced over the 45 days of storage at room temperature and relative humidity (temperature 23-30 °C and relative humidity of 31-66%) [101]. The bioactive compound loss was attributed mainly to the type of packaging material used (transparent cellophane bags) [101]. The vitamin C content in guava leathers reduced (up to 38.48%) after 90 days of storage in different packages (polypropylene (PP), butter paper (BP), metalized polyester polyethylene (MPP), and aluminum foil (AF)), where leathers packaged in MPP and stored at room temperature showed lower losses of vitamin C (20.80%), while leathers stored in AF under refrigeration (10 °C) showed vitamin reduction of only 2.34% [34]. Safdar et al. [17] also reported that AF promoted greater retention of ascorbic acid content (27.74 mg 100 g^{-1}) in guava leathers stored at 6 °C for 240 days.

4.2.2 *Sensorial*

The taste of fruit leathers can be attributed to the sugar content in the pulp of fresh fruit [25]. The sweetness of leather varies according to the type of fruit and the storage time [84]. The presence of acids and sugars creates a pleasant sensation on the palate, which is perceived by specialized taste buds [17].

The main objective of sensory analysis of fruit leathers is to evaluate the attributes and overall preference to select the best formulation [26, 28]. The sensory attributes were used as quality factors of the final product [25, 27]. Most studies investigated the sensorial acceptability of fruit leathers and, consequently, the effect of leather compositions on the sensorial attributes. Figure 3 presents the similarity analysis using the Iramuteq® software (Interface R pour les Multidimensionnelles Analyzes de Textes et de Questionnaires) in a new textual corpus based on the sensory analysis methodologies (total of 30) reported in articles about fruit leathers. The most investigated sensory attributes in fruit leathers reported in the literature were color, taste, flavor, and texture. Huang and Hsieh [61] indicated that fruit leathers' most appreciable sensory characteristics are shiny surface, sweet and tart tastes, and aroma.

The sensory analyses generally used are Quantitative Descriptive Analysis (QDA) and Hedonic Scale, which can also be used together. The QDA is a broad and informative sensory assessment method related to consumer acceptance, with the analysis generally consisting of 10-12 trained tasters and with unstructured line scales (~15 cm) used to describe the intensity of the evaluated sensory attributes. While the hedonic scale has untrained tasters (75-150) who must evaluate the samples in terms of the intensity of liking and disliking [105].

In Figure 3, the terms that have been used frequently were presented, and in relation to the hedonic scale, this is commonly performed with a 9-point scale ranging from 'like extremely' and 'dislike extremely'. Sensory tests on fruit leathers were also performed using electronic nose and tongue to mainly evaluate odors, flavors, and tastes [21].

The Quality Function Deployment (QFD) methodology was applied to define customer needs, and the House of Quality (HOQ) product planning matrix in conjunction with the 9-point hedonic scale test and QDA to develop kiwi leathers, and the consumers preferred fruit leathers with more concentrated fruit flavor, less hard, sweet and with good chewability [85].

The addition of maqui extract to apple and quince leathers increased the content of bioactive compounds, using a 9-point hedonic scale, reducing the tasters' acceptance in relation to sensory attributes (color, sweetness, flavor, and tartness) [26]. Based on the test using a 7-point hedonic scale, the greater acceptability (color, flavor, hardness, chewiness, and overall acceptability) by soursop leathers was observed with a maximum addition of 40% of oatmeal. In comparison, soursop leather without oatmeal showed less acceptability due to the sour taste characteristic of soursop [24].

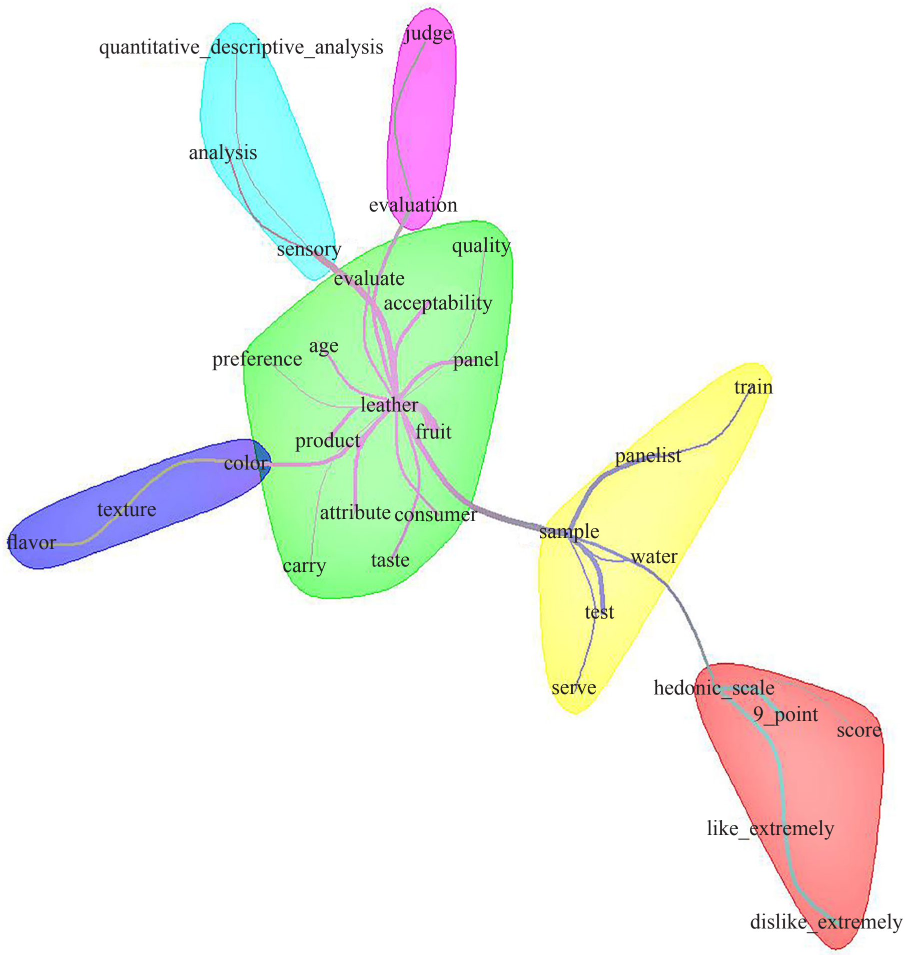

Figure 3. Similarity analysis between sensory analysis methodologies for fruit leathers

The guava leathers with papaya in different concentrations showed less acceptance after 4 months os storage than the first storage days. The mixture of guava and papaya contributed to maintaining sensory properties (color, texture, and flavor) and improved nutritional value [95]. These results corroborate which papaya: guava leathers (40:60 w/w) were more sensorial accepted [66]. Apple leathers showed higher scores for sweetness, while quince leathers had higher acidity scores, and both leathers showed similar soluble solids [26]. Apple and strawberry leathers were more accepted by the tasters than apple and kiwi leathers, possibly due to strawberry's red color, intense smell, and sweet flavor characteristics [27]. Color can be an important attribute, affecting food appearance and influencing consumers' perceptions [90].

The tasters appreciated the appetizing mixture (thyme seed powder, mint powder, salt, and black salt) addition in ginger and plum leathers, promoting acceptability for the color, texture, flavor, taste attributes, and overall acceptability [28]. The increase in the content of soy protein concentrate reduced the sensory acceptability of mango leathers as it influenced color, flavor, and texture; however, the addition of sucrose improved the sensory parameters, as well as the addition of powdered milk, except in relation to taste [93].

Relative humidity can affect sensory attributes and, consequently, the acceptability of fruit leathers, as it can alter crunchiness, elasticity, and softness [22]. The low water activity hampered the shear force of mango leathers, and the tasters were considered a hard texture, but the flavor had high acceptance (85%). The authors also stated that the lack of knowledge of this product type in each region can cause low consumer acceptability [14].

The most sensorial accepted leathers by consumers are with the highest fruit flavor, sweet, slightly acidified, chewable, soft texture, less hardness, and a pleasant taste in the mouth.

4.2.3 *Texture*

The texture analysis of fruit leathers is an important characteristic, including hardness and fracture properties [24]. Texture attributes can be important in consumer acceptance of a new product [100]. Fruit leathers are generally tasty, chewy, high in fiber and carbohydrates, and can be easily handled [100]. Fruit leathers must have a soft texture, which can be acquired with higher moisture content, but with reduced water activity, for microbiological stability [5].

Texture analysis is generally performed using a texturometer, and some of the most researched parameters include adhesiveness [29, 61], chewiness [12, 24, 61], cohesiveness [33, 86], elongation [64, 67, 90], hardness [12, 33, 89], gumminess [12, 68], springiness and rupture strength [67, 68].

The variation of hardness (5.63-8.27 N), adhesiveness (0.49-0.74 MJ), and cohesiveness (0.44-0.67) of mango leathers with different concentrations of sugar and pectin were observed, and a formulation containing 10% sugar and 1% of pectin produced better quality leathers in relation to texture parameters [33]. The mixture of mustard leaves with fruit puree increased leather hardness, and the jackfruit puree increased the hardness and gumminess [29]. It was observed that the leather's hardness was inversely proportional to the moisture content. Sánchez Riaño et al. [67] reported an increase in tensile strength with the addition of pectin, arabic gum, maltodextrin, and carboxymethylcellulose, respectively.

The most influential parameters of tamarind leather's characteristics were plasticity, elasticity, resilience, cohesiveness, and hydrocolloid concentration [86]. Leathers from two papaya cultivars with the addition of pectin differed significantly in hardness (483.60-490.48 g f^{-1}) [19]. The texture comparison of leather can be difficult due to the fruit's genetic structure difference and adding ingredients, which can influence the texture quality [19].

Increasing the concentration of pectin in leathers of concentrated pear juice promoted greater hardness, cohesiveness, springiness, and chewiness, while the addition of softened corn syrup decreased springiness and increased adhesiveness [61]. Similar results were reported by Vatthanakul et al. [85] on the increased tensile strength from adding pectin and glucose syrup. Adding protein concentrate, sucrose, and skimmed milk powder reduced the extensibility of mango leathers [93].

Properties were affected by the composition of peach leathers with the addition of hydroxypropyl methylcellulose and cellulose micro/nanofibrils, increasing the permeability to moisture and elongation at break, as well as the reduction of resistance and stiffness [90]. A reduction in the leather's puncturing force was verified with the addition of concentrated apple juice (20-40%), which also increased sugar content and contributed to its softening [5].

The pectin (1.5%) resulted in increased hardness (tensile force and work) of pineapple leathers; however, there was a reduction of these properties after the addition of glucose syrup (6%) [63]. The hydrocolloids (1-3%) increased the extensibility and energy to rupture of mango leathers containing guar gum, sodium alginate, pectin, carboxymethyl cellulose, and gum acacia, respectively, and specifically guar gum or pectin can modify texture without affecting the drying rate of leathers [87]. The pectin (6%) addition increased the hardness of papaya leathers, promoting the formation of a firm gel structure [19]. The date and tamarindo leathers, with the addition of starch corn, pectin, maltodextrin, or guar gum (1-3 g 100 g^{-1} puree), increased the hardness (7-48 N) and gumminess (2.4-8 N), and reduced cohesiveness (0.4-0.1) and springiness (4.4-1.9 s) according to the addition of hydrocolloids [86]. The hardness effect may depend on several factors, such as the food's type, composition, and processing conditions [89].

The xanthan gum (0-4%), locust bean gum (0-10%), and pregelatinized starch (0-10%) increased the resistance to extension from 20 to 1,386.34 g of leathers [70]. The optimal formulation was 7.5% locust bean gum and 2.5% pregelatinized starch, promoting resistance to an extension of 346.48 g [70]. The maltodextrin (0-15 g 100 g^{-1} mixture) in apple leathers increased the puncture force (143%), puncture deformation (35%), and maximum amplitude (140%), and the transition from crispy to deformable occurred after hydrating the leathers between 0.22 and 0.44 water activities [35].

The 1.0% of gelatin in myrtle leathers reduced hardness, gumminess, and chewiness, while the addition of 0.2% carrageenan and 4.0% potato starch increased these parameters; however, the addition of hydrocolloids did not influence springiness and cohesiveness [12]. The soy protein (4.5-9.0%), sucrose, and skim milk powder reduced the extensibility and energy break in relation to the control without additives, and extensibility was most affected by the addition of sucrose. In contrast, energy break was most affected by skim milk powder [93].

5. Conclusions

This review article covered the usual terminologies for dry products developed from fruit purees, their physical-chemical parameters, and the influence of the leathers composition on the quality attributes, including bioactive compounds and sensory and texture properties. Several terminologies have emerged to describe this type of product, and some studies reported aspects that may be differentiating factors between products (fruit leathers, pestil, fruit bars, and films). It was possible to observe that leathers present greater thickness than edible and pestil films, as well as greater water activity, and that the spread thickness of fruit bars is greater than that of leathers. Using Iramuteq® Software shows that leathers, pestil, and fruit bars have similar characteristics but differ from edible films. However, it was not possible to establish specific parameters that could influence the terminology, and fruit hides are the most common terminology. The bioactive compounds are naturally found in the fruits as a basis for structuring the leather. Other fruits, concentrates, or extracts were used together to improve leather's quality and nutritional value. Adding ingredients can alter the texture and sensory properties, directly influencing product acceptability. It is evident that many characterizations are not standardized, thus making it difficult to compare the products created.

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Conflict of interest

The authors declare no competing financial interest.

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