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ORIGINAL RESEARCH ARTICLE

Functional, antioxidant and organoleptic study of sauces prepared with *Spondias dulcis forst* (amra): An underutilized fruit

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ABSTRACT

In the present study, the underrated fruits of *Spondias dulcis frost* were utilized for the development of unconventional sauces. Two distinct sauces were prepared: one using the pulp of semi-ripened Amra fruit, and the other using its peels. The homogenized ingredients were cooked in an open vessel. Both sauces exhibited dose-dependent 1,1-diphenyl-2-picryl-hydrazyl (DPPH) reduction. The *R*-values of the DPPH free radical scavenging activity of Amra peels and pulp sauces were found to be 0.9873 and 0.9759, respectively. The sauce made with the pulp of fruit showed a significantly stable emulsion and lower syneresis values, whereas the sauce prepared with fruit peels was more astringent with a significantly higher titratable acidity ($p < 0.05$). The mineral content and brix of sauce made with fruit pulp were found to be significantly higher. The sensory characteristics of both sauces were found acceptable by sensory assessors. However, the taste of pulp sauce was found to be significantly better than that of fruit peel sauce. The findings suggest that the pulp and peels of Amra fruits could be employed for the development of antioxidant-rich sauces; however, the application of Amra peels for the formulation of potential value-added sauces, jams, and other condiments would reduce manufacturing waste and cost.

Keywords: amra fruit; sauce; sustainability; nutraceuticals; valorization

1. Introduction

The tropical flowering plants that bear drupe fruits fall into the Anacardiaceae family. This family includes numerous genera of economic significance, such as the genus *Spondias*. The *Spondias* genus consists of 8–12 species, approximately[1]. It is dispersed across tropical and sub-tropical regions of the world. The tree bears edible fruits in clusters of 3–20 or more. The colloquial names of fruits are cajamanga, hog plum, amra, golden apple, ambarella, yellow plum, and otaheite apple[2]. The skin of the fruit is tough, the pulp of varying thickness is yellow, and a single large seed is present. The seeds of Amra fruit are difficult to separate from the pulp and often have strong woody fibers projecting into the pulp[3]. The proximate analysis values of *Spondias dulcis* fruits per 100 g of raw pulp are: 157.30 calories, crude fiber (0.85%–3.60%), total solid (14.53%–40.35%), moisture content (59.65%–85.47%), protein content (0.50%–0.80%), fat content (0.28%–1.79%), sugars (8.05%–10.54%), total titratable acidity 0.47%, and ascorbic acid content (42 mg/100g). The pectin content of unripe fruits is 9.76%[2]. The *Spondias* tree is considered a medicinal plant, and its bark,

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leaves, and fruits have been used to treat various ailments since ancient times. Recent studies have extensively explored the antioxidant, anti-inflammatory, anti-ulcer, antimicrobial, antidiabetic, and anticancer potential of its stems, leaves, and fruits[4–6]. Furthermore, the juice of amra fruit has been studied for its quality and techno-functional properties after different treatments[7,8].

In the current era, junk food has become the major source of nutrition in various parts of the world. Many health issues are growing due to reasons like unhealthy lifestyles, unwholesome food choices, etc.[9]. The junk food has more calories but poor nutritional density. Junk foods are usually consumed with different kinds of condiments, like garlic sauce, ketchup, mayonnaise, etc. There is an alarming need to provide nourishing food choices to the mass population.

The aim of the present study is to exploit the underutilized *Spondias dulcis* fruit in Pakistan and develop a value-added sauce. Also, this study targeted the effective utilization of fruit peels, which are usually discarded as waste and end up in landfills. To the best of our knowledge, this wild fruit has not been explored in Pakistan for its edible potential, nor has the potential of its pulp and peel been compared for the development of sauces and condiments.

2. Materials and methods

The amra fruit in the semi-ripen stage was procured from a local market, while the remaining ingredients were purchased from a superstore in Karachi, Pakistan. All reagents used for the present study were of analytical grade.

2.1. Formulation of *Spondias dulcis* fruit sauce and storage

Both rind (RS) and pulp (PS) sauces of amra fruit were prepared in an open vessel, as shown in **Figure 1**. The following ingredients were used for the formulation of sauces: fruit peel/fruit pulp (17.96%), oil (4.61%), onions (3.83%), garlic (0.77%), green chili (1.54%), red chili (0.26%), salt (0.26%), sugar (2.55%), water (63.97%), and citric acid (4.25%). The ingredients were homogenized and subsequently cooked together for 30 min at 100 ℃ on a hotplate with occasional stirring. The prepared sauces were stored at refrigeration temperature (4 ℃) in plastic beakers covered with cling wrap. The study of the freshly prepared sauces was conducted on the same day of preparation (0 h).

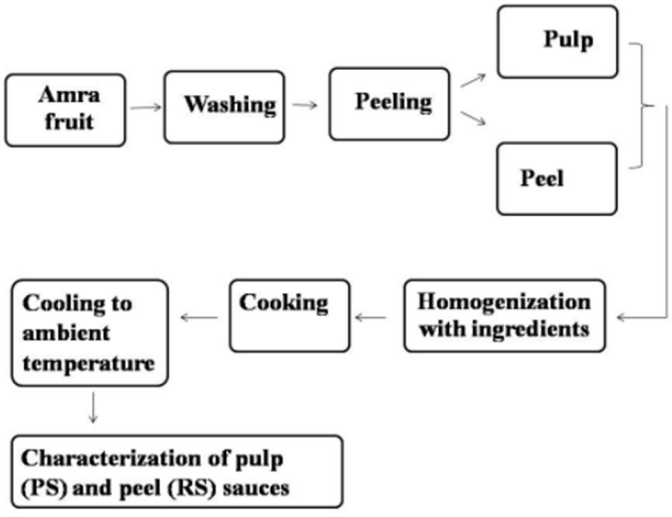

Figure 1. Flow chart for the production of sauces.

2.2. Antioxidant activity of the sauce by 1,1-diphenyl-2-picryl-hydrazyl (DPPH) radical scavenging

The DPPH scavenging activity of sauces was determined using a slightly modified method outlined by Hossain et al.[10]. The diluted extracts of the sauces (0.15 mL) were added to 0.9 mL of the methanolic DPPH solution. After 20 min, the absorbance of the blends was recorded at 517 nm using a UV-visible spectrophotometer (Model V670, JASCO Corporation, Tokyo, Japan). The scavenging activity (SA) was calculated as follows: DPPH scavenging activity (%SA) = (1 − X/C) × 100, where *X* is the absorbance of sauce extracts and *C* is the absorbance of control.

2.3. Titartable acidity (TA) and pH of sauce

The titratable acidity of *Spondias* fruit sauces was determined as the percent of citric acid by titration with a NaOH (0.1 N) solution using phenolphthalein as indicator[11]. The TA of freshly prepared sauces was calculated by using the following equation.

$$\text{TA}(\%) = \frac{\text{Vol of titre} \times \text{Normality of titer} \times \text{eqv. wt. of dominent acid}}{\text{Vol of sample} \times 1000} \times 100 \quad (1)$$

The pH of sauce was determined using a digital hand handled pH meter (AD 11, ADWA kft. Europe) which was calibrated by using standard pH buffer.

2.4. Soluble solids (SS) of *Spondias dulcis* fruit sauces

The measurement of the soluble solids in the sauce was made by using a hand-held refractometer (ATAGO, Japan). The evaluation was done at ambient temperatures. The values were expressed as degrees Brix (°B).

2.5. Syneresis index of *Spondias dulcis* fruit sauces

The syneresis of sauces was determined by the methodology of Moin et al.[12]. Both RS and PS sauce samples (15 g) were filled in screw-capped centrifuge tubes and stored at 4 ℃ for a day. Subsequently, the tubes were centrifuged at 6000× g for 25 min at 25 ℃ using a centrifuge machine (Z 200 A, Hermle Labortechnik, Germany). The separated supernatant was then cautiously removed following centrifugation and weighed. The syneresis index of amra peels and pulp sauces was determined by the following equation.

$$\text{Syneresis}(\%) = \frac{\text{Weight of water sperated from sauce(g)}}{\text{Sample weight (g)}} \times 100 \quad (2)$$

2.6. Inorganic matter in *Spondias dulcis* fruit sauces

Mineral content of the PS and RS sauces was analyzed by burning at 500 ℃ for 8 h[13].

2.7. Emulsion stability of *Spondias dulcis* fruit sauces

The emulsion stability of amra sauces was evaluated by the procedure described by Kantekin et al.[14] with some modifications. Freshly prepared sauce samples (25 g) were filled in screw-capped centrifuge tubes and stored in a conduction oven at 80 ℃ for 1 h. Afterwards, the screw-capped tubes were centrifuged at 6300× g for 30 min at ambient temperature in a centrifuge (Z 200 A, Hermle Labortechnik, Germany). The separated liquid was carefully decanted and weighed. The emulsion stability of both sauces was calculated using the following equation.

$$\text{Emulsion stability}(\%) = \frac{\text{sample weight (g)} - \text{decant weight (g)}}{\text{sample weight (g)}} \times 100 \quad (3)$$

2.8. Sensory evaluation of *Spondias dulcis* fruit sauces

The organoleptic acceptance of the sauce was evaluated using a hedonic ranking test (5 = like extremely, 1 = dislike extremely). The sensory parameters determined were appearance, texture, taste, aroma, mouthfeel, and overall quality. The sensory assessment was conducted by semi-trained panelists (n = 30) between the ages of 18 and 35 at the Department of Food Science and Technology, University of Karachi. The serving plates were marked with three-digit random codes and then served to the panelists. Clean drinking water was provided to the assessors to cleanse their palates between testing samples. The samples were served at ambient temperature[15].

2.9. Statistical analysis of experimental data

A paired sample t-test was applied to evaluate the significant difference between mean values using IBM SPSS version 22. The values are means of triplicate (n = 3) except for sensory evaluation, for which (n = 30).

3. Results and discussions

3.1. Antioxidant activity of the sauces

The free radical scavenging by using stable DPPH was found to be concentration-dependent in both peel and pulp sauce samples (**Figure 2**). The R-values of the DPPH free radical scavenging activity of amra peels and pulp sauces were found to be 0.9873 and 0.9759, respectively. The higher antioxidant capacity of sauces could be due to the presence of polyphenols and the higher ascorbic acid content present in the semi-ripening stage of amra fruit[16]. No significant difference was found in the percent scavenging of sauces prepared with the rind (RS) and pulp (PS) of amra. However, the formulation of amra fruit sauce is a unique and underexplored way to enhance the antioxidant potential of dips and condiments. Moreover, the similar antioxidant potential of pulp and peel would promote the incorporation of rinds and eventually reduce the raw material cost and waste generation during processing.

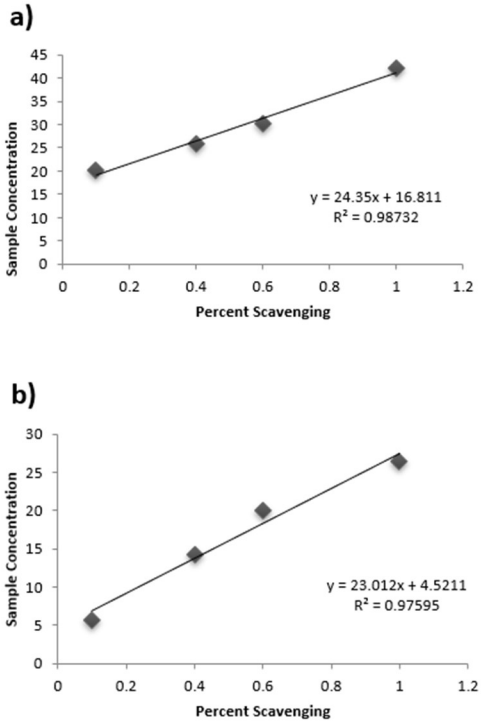

Figure 2. Antioxidant activity of the sauce by 1,1-diphenyl-2-picryl-hydrazyl (DPPH) radical scavenging.

3.2. Titartable acidity (TA) and pH of sauce

The mean values of titratable acidity (TA) and pH of sauces are shown in **Table 1**. The TA was calculated as % citric acid. The acidity of RS (2.46%) was significantly higher than PS (1.95%), suggesting the stringent taste of the sauce prepared with fruit peel. This is also evident from the pH of the sauces (**Table 1**). The pH of RS and PS was 2.36 and 3.53, respectively. Therefore, the sauces in this study fall into the category of very acidic foods (pH < 4.0), which curtails the requirement for harsh thermal treatment, which could degrade the bioactive compounds and negatively influence the nutritional quality of the product[17]. Furthermore, the pH of the sauce prepared with golden apple pulp was in accordance with the study on golden apple pulp chutney in Bangladesh, which ranged from 3.12 to 3.72[18]. Whereas, the pH of RS sauce was found to be similar to that of a that of a traditional pomegranate sour sauce sample commercially produced in Turkey[19].

Table 1. Functional properties of *Spondias dulcis* fruit pulp and rind sauces[a].

Sample	pH	Ash (%)	Emulsion stability (%)	Syneresis (%)	Titrable acidity (%)	Brix (˚B)
RS	2.36a	0.096a	3.026a	4.313a	2.465b	16.166a
PS	3.53b	0.156b	5.225b	2.496b	1.948a	18.166b

[a] means within a column with different alphabets are significantly different from each other. RS: Sauce prepared with fruit rind; PS: Sauce prepared with fruit pulp.

3.3. Soluble solids (SS) of *Spondias dulcis* fruit sauces

The soluble solids content is shown in **Table 1**. The soluble solid content varies between different fruit varieties and maturity stages. Significantly higher brix was found in PS than RS ($p < 0.05$). This could be due to the comparatively higher sugar content in the pulp of *Spondias* fruit than the rind. Reduced brix in RS could be due to the presence of higher amounts of structural polymers in the peels of fruit. Also, the thickness of the peel and the peeling procedure could affect the total soluble solid content of the sauce prepared with fruit rind. The soluble solid content of both RS and PS sauces was found to be in accordance with light and traditional ketchup marketed in Brazil, which ranged from 10.39 to 33.24 °Brix[20].

3.4. Syneresis of sauces

The syneresis index is an estimation of leached-out free water from a paste under the application of centrifugal force. However, the quantity of water released from a semi-solid gel after refrigerated or frozen storage is referred to as expelled water[21]. The exudation of water from sauces is considered a negative quality attribute. Percent syneresis in RS and PS was found to be 4.313% and 2.496%, respectively (**Table 1**). The evaluation suggests significantly higher stability of RS than PS on cold storage after 24 hours. This could be due to the difference in fibrous composition and soluble solid content (**Table 1**) of the fruit rind and pulp of Amra fruit.

3.5. Inorganic matter in sauces

The inorganic residues remaining after ignition or complete oxidation of organic matter in a biomass are referred to as ash or total ash[22]. The ash content evaluation of a food sample is a fraction of the proximate analysis for nutritional assessment. It is considered an important quality attribute of processed foods. The ash content of PS was found to be significantly higher than that of RS (**Table 1),** suggesting that a higher concentration of minerals is present in the pulp of amra fruit. The mineral content of sauces in the present study was found to be in accordance with sauces and ketchups marketed in Bangladesh, which ranges between (0.10%–1.43%)[23].

3.6. Emulsion stability of *Spondias dulcis* fruit sauces

The stability of an emulsion is defined as the ability to resist changes in the physicochemical properties of the emulsion over time. The emulsions in food may become unstable due to many different physicochemical mechanisms, such as gravitational separation, phase inversion, flocculation, and coalescence [24]. The percent emulsion stability of PS was found to be significantly higher than that of RS ($p < 0.05$). Higher emulsion stability reflects the better shelf stability of PS sauce upon higher temperature (80 ℃) exposure as compared to RS. The difference in pH of both sauces could affect the stability of the emulsion. pH closer to the isoelectric point of the proteins present leads to a stable emulsion[25].

However, both sauces exhibited water exudation after exposure to elevated temperatures, followed by centrifugation (**Table 1**). This attribute highlights the need for an emulsifier in the formulation of sauces prepared with amra fruit rind and pulp to ensure stability during temperature fluctuations during storage and transportation.

3.7. Sensory assessment of sauces

The sensory attributes of foods are associated with their composition and microstructure. The findings of the sensory assessment of sauces are presented in **Table 2**. The assessors could not find any significant difference in the appearance, texture, aroma, mouthfeel, or overall quality of both sauces. However, the hedonic scores for taste were found to be significantly higher for PS than RS. In the study of Bhuiyan et al.[18], it was found that chutney with a higher concentration of golden apple pulp secured higher hedonic ranking scores in terms of color, flavor, texture, and overall acceptability. However, the present findings suggest that the that the incorporation of *Spondias dulcis* fruit rind along with pulp in the sauce recipe would reduce production and waste management costs without altering the overall acceptability of the sauce.

Table 2. Sensorial properties of *Spondias dulcis* fruit pulp and rind sauces[a].

Sauce samples	Appearance	Texture	Aroma	Overall quality	Taste
RS	2.000[a]	2.800[a]	5.500[a]	3.700[a]	3.100[a]
PS	3.100[a]	2.700[a]	5.000[a]	3.900[a]	5.00[a]

[a] means within a column with different alphabets are significantly different from each other. RS: Sauce prepared with fruit rind; PS: Sauce prepared with fruit pulp.

4. Conclusion and recommendations

The study exploited an underutilized wild food commodity in Pakistan for the preparation of a functional sauce. The development of an antioxidant-enriched sauce offers a healthy alternative to commercially available condiments. Sensory analysis outcomes disclosed that sauces prepared with fruit pulp and peels of fruit were both acceptable to the assessors. The utilization of whole fruit will reduce fruit waste and decrease production expenses. Also, various combinations of pulp and rind ratios could be studied to overcome the shortcomings of individual rind and pulp sauces.

5. Novelty statement

Studies on the utilization of *Spondias dulcis* fruits in Pakistan are lacking. Moreover, no comparison of *Spondias dulcis* pulp and rind has been reported. This study aims to develop value-added products from an underutilized food commodity while also reducing food waste and promoting its effective utilization.

Author contributions

Conceptualization, AM and MQ; methodology, AM and MQ; software, AM and AK; validation, AM and AK; formal analysis, MQ; investigation, MQ and AM; resources, AM; data curation, MQ; writing—original draft preparation, AM; writing—review and editing, AM and AK; visualization, MQ; supervision, AM; project administration, AM and AK; funding acquisition, AM through Dean Science Research Grant, University of Karachi. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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