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STANDARDIZATION OF INGREDIENTS FOR THE PREPARATION OF WOOD APPLE FRUIT LEATHER

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ABSTRACT

The present investigation entitled "Standardization of ingredients for the preparation of wood apple fruit leather" was conducted in the Department of Postharvest Management, College of Horticulture, Mudigere, during 2024–2025. The study aimed to standardize the proportions of wood apple fruit pulp, sugar, and jaggery for the preparation of nutritionally rich and organoleptically acceptable fruit leather. The experiment was laid out in a Completely Randomized Design (CRD) with ten treatments and three replications. Among the treatments, T_6 (Wood apple fruit Pulp 40 % + Jaggery 60 %) recorded the desirable physical parameters with the maximum leather recovery percentage (81.46 %), colour values *L** (29.72), *a** (5.83), *b** (-2.93) and total soluble solids (66.95 °Brix), total sugars (66.93 %), carbohydrate (65.11%), along with superior chemical composition comprising ascorbic acid (16.65 mg / 100g), total phenols content (184.91mg GAE / 100g), total antioxidant activity (74.87 mg AAE / 100g), fiber (5.05%) and highest sensory evaluation scores observed in colour (9.00), flavour (8.10), texture (8.20), taste (8.40), overall acceptability (8.42).
***Keywords* :** Wood apple fruit pulp, Jaggery, Sugar, Leather, Standardization

Introduction

Wood apple (*Limonia acidissima* Linn.) belongs to the family Rutaceae and is indigenous to South India and Srilanka. It is one of the hardiest fruits grown in semi-arid regions of India. It is an acidic in unripe condition but gives pleasant flavour when ripe. (Thakur *et al.*, 2020). It is commonly grown as a border plant in addition to being found in jungles. Common names in English include wood-apple, elephant-apple, monkey fruit, curd fruit and Kathbel and in Northern India it is called as Kaitha. This plant is prescribed as a traditional medicine for the treatment of various ailments (Khare, 2007).

Fruit leather is a dried fruit pulp, chewy and flavourful. When water is removed from fruit pulp by drying, sugars, acids, fibre and many vitamins and minerals become concentrated in the remaining solid part of the fruit leather. Fruit bar, leather is the term used for the products prepared by dehydration of fruit pulp with or without acid and sugar. This makes dried fruits, high in sugar and other nutrients. Dried fruits provide a nutritious way to satisfy a sweet tooth. There are many fruits bar and candy available in the market, but mango bar is the most popular and attractive among consumers in the local market due to its good taste.

In recent years, consumers have become more health conscious in their food choices but have less time to prepare healthy meals. Consumers are also in search of foods which offer them extra nutrition, ease of use and attractive and convenient packages.

Materials and Methods

The present investigation was carried out at the Department of Postharvest Management, College of

Horticulture, Mudigere. The experiment was laid out in a Completely Randomized Design (CRD) with ten treatments and three replications.

Treatment Details:

Treatments	Treatment combinations
T_1	Wood apple fruit Pulp (40 %) + Sugar (60 %)
T_2	Wood apple fruit Pulp (45 %) + Sugar (55 %)
T_3	Wood apple fruit Pulp (50 %) + Sugar (50 %)
T_4	Wood apple fruit Pulp (55 %) + Sugar (45 %)
T_5	Wood apple fruit Pulp (60 %) + Sugar (40 %)
T_6	Wood apple fruit Pulp (40 %) + Jaggery (60 %)
T_7	Wood apple fruit Pulp (45 %) + Jaggery (55 %)
T_8	Wood apple fruit Pulp (50 %) + Jaggery (50 %)
T_9	Wood apple fruit Pulp (55 %) + Jaggery (45 %)
T_{10}	Wood apple fruit Pulp (60 %) + Jaggery (40 %)

Procedure for preparation of wood apple fruit leather

Wood apple fruits were selected and the pulp was extracted by scooping method and stored under refrigeration for further use. Sugar and jaggery were incorporated into the pulp at as per treatment concentration. The mixture was gently cooked over low heat with continuous stirring and then spread uniformly over trays to obtain a 3 to 5 mm thick layer. Drying was carried out in a dehydrator at 60 °C for 6 hours. The dried fruit leather was cut into pieces and packed in polypropylene material for storage.

Results and discussion

Physical parameters of wood apple fruit leather

The data of on physical parameters of wood apple fruit leather were presented in the table 1. The low water activity in fruit leather ensures microbial safety, enhances shelf life and maintains desirable texture and quality. There was no significant difference observed in all the treatments. The treatment T_1 (Wood apple fruit pulp 40 % + Sugar 60 %) recorded 0.62 and the highest water activity (a_w) was observed in T_{10} (Wood apple fruit pulp 60 % + Jaggery 40 %) (0.71). Water activity (aw) is a critical parameter in determining the microbial stability, shelf life and textural quality of fruit leather. The microbiological safety was determined by the aw of the fruit bar, The aw in the food ranges from 0 to 1, where fresh food has aw near to 1 and in dried food aw is near to 0 (<0.60). Concha-Meyer *et al.* (2016) opined aw more than 0.85 allow the microbial growth. In the present study, the water activity of the prepared wood apple leather increased with increased concentration of wood apple pulp and it ranged from 0.62 to 0.71. Also, the higher sugar and jaggery concentration increase the osmotic potential and reduce the free water in the product leads to lower water activity. The similar results are reported by Kushner *et al.* (1979) in Jamun leather. However, the water activity in the present treatments was low enough to arrest the microbial growth. Similar findings are seen by Singh (2008) in the preparation of wood apple and guava leather of quality analysis.

Fruit leather generally had the moisture content in the range 12 to 25 per cent. Moisture content in fruit leather directly affects its texture, flavour, shelf life and handling properties. Among all treatments there were no significant difference was observed that shows moisture content within the range and the lowest moisture content (14.16 %) recorded in T_1 (Wood apple fruit pulp 40 % + Sugar 60 %), whereas the maximum moisture content (14.28 %) was found in T_{10} (Wood apple fruit pulp 60 % + Jaggery 40 %). Moisture is an important parameter in fruit bar/ leather that governs the quality, safety, palatability and shelf life. Maintaining the right level is essential for producing stable, chewy and nutritious product. In the present study, the moisture content of the wood apple fruit leather with different combinations of pulp, sugar and jaggery, recorded no significant differences varied from 14.16 to 14.26 per cent (Table 1). According to FSSAI (2006), the moisture content of fruit bar should not exceed 20 per cent. In the present study the prepared leather has moisture content less than 20 per cent in accordance with FSSAI, 2006. Similar findings were observed in fruit leather of guava by Khan *et al.* (2014).

Table 1 : Effect of ingredients on physical parameters of wood apple fruit leather

Treatment details	Water activity (a_w)	Moisture content (%)	Leather recovery percentage (%)	Colour value		
				*L**	*a**	*b**
T_1	0.62	14.16	79.43^b	28.92^d	5.76^{ab}	-2.29^c
T_2	0.64	14.18	76.45^c	27.43^e	5.75^{ab}	-2.23^c
T_3	0.65	14.21	74.87^e	27.39^{ef}	5.72^{ab}	-2.21^c
T_4	0.67	14.23	73.18^f	27.31^{ef}	4.83^d	-2.20^c
T_5	0.69	14.25	72.48^h	27.28^f	4.74^d	-1.96^d
T_6	0.65	14.19	81.46^a	29.72^a	5.83^a	-2.93^a
T_7	0.66	14.21	79.31^b	29.65^a	5.81^{ab}	-2.87^a
T_8	0.68	14.23	76.59^c	29.44^b	5.79^{ab}	-2.46^b

T_9	0.69	14.26	75.41^{d}	29.31^{bc}	5.68^{b}	-2.21^{c}
T_{10}	0.71	14.28	72.65^{g}	29.19^{c}	5.43c	-2.18^{c}
S.Em±	**0.02**	**0.02**	**0.07**	**0.06**	**0.06**	**0.07**
CD @ 1%	**NS**	**NS**	**0.21**	**0.20**	**0.19**	**0.21**

Fruit leather recovery is the percentage yield of dried fruit leather from fruit pulp, affected by pulp solids, added ingredients and drying method. It indicates the processing efficiency and useful for comparing the formulations. There was statistically the highest leather recovery was achieved in T_6 (Wood apple fruit pulp 40 % + Jaggery 60 %) (81.46 %), which was followed by T_1 (Wood apple fruit pulp 40 % + Sugar 60 %) (79.43 %) and T_7 (Wood apple fruit Pulp 45 % + Jaggery 55 %) (79.31 %) and the lowest leather recovery was noted in T_5 (Wood apple fruit Pulp 60 % + Sugar 40 %) (72.48 %). In the present study the wood apple fruit leather incorporated with 40 per cent pulp and 60 per cent jaggery had the highest leather recovery percentage which was comparable with treatment containing 40 per cent pulp and 60 per cent sugar. The fruit naturally contains 10 to 20 per cent sugar, in the present study particularly when jaggery was added, the solid content rises so less water needs to be added to reach the leathery texture which results in higher recovery in T_6 (81.46%) (Table 1). Also, jaggery binds to water and increases viscosity which reduces stickiness and shrinkage improving net recovery after drying compared to sugar. Similar findings were recorded in papaya and guava fruit leather by Kumar *et al.* (2017).

Colour values in fruit leather measures the appearance, quality and consumer appeal through objective measurement. The lightness values of different wood apple fruit leather formulations varied between 27.28 and 29.72. The highest *L** value recorded in T_6 (Wood apple fruit pulp 40 % + Jaggery 60 %) (29.72), which was statistically on par with T_7 (Wood apple fruit Pulp 45 % + Jaggery 55 %) (29.65) and the lowest *L** value was observed in T_5 (Wood apple fruit Pulp 60 % + Sugar 40 %) (27.28). *L** value reflects a darker, richer tone typically associated with higher anthocyanin or phenolic content, or darker fruit bases like wood apple, bilberry or blackcurrant of the prepared fruit leather. The higher darkness values were obtained in T_6 (29.72) which was followed by T_1 (28.92) the possible reason could be that the wood apple pulp is naturally dark brown due to tannins and phenolic compounds, addition of jaggery (which has a lighter golden brown colour compared to wood apple pulp dilutes these pigments, making the overall blend appear lighter when compared to other treatments (Table 1). These reasons were better supported by the findings of Ahmad *et al.* (2005) in drying of papaya and tomato leather and Kumar *et al.* (2017) in studying the effect of sugar-acid mixture on the stability of papaya and guava fruit leather.

Similarly, the T_6 (Wood apple fruit Pulp 40 % + Jaggery 60 %) treatment was found to have maximum *a** value (5.83) which was on par with the values of T_7 (Wood apple fruit Pulp 45 % + Jaggery 55 %) (5.81), T_8 (Wood apple fruit Pulp 50 % + Jaggery 50 %) (5.79), T_1 (Wood apple fruit pulp 40 % + Sugar 60 %) (5.76), T_2 (Wood apple fruit Pulp 45 % + Sugar 55 %) (5.75) and T_3 (Wood apple fruit Pulp 50 % + Sugar 50 %) (5.72), while the minimum *a** value was recorded in T_5 (Wood apple fruit Pulp 60 % + Sugar 40 %) (4.74). The treatment T_6 (5.83) value showed highest *a** value which was statistically similar with T_1 (5.76) of Jaggery-added wood apple fruit leather it was mainly due to the natural reddish pigments of jaggery, caramelization of sugar and maillard reaction products, which intensify redness during drying. An increase in *a** value in jaggery-added wood apple fruit leather is beneficial, as it improves appearance and consumer appeal, provided it is within an acceptable range. Similar increase in *a** value was observed by Shrivastava and Kumar (2002) in wood apple leather and Kumar *et al.* (2017) in studying the effect of sugar acid ratio in stability of papaya and guava fruit leather.

The highest *b** value in prepared wood apple fruit leather was noticed in T_5 (Wood apple fruit Pulp 60 % + Sugar 40 %) (-1.96), and T_1 (-2.29), which was significantly different from all other treatments and the lowest *b** value recorded in T_6 (Wood apple fruit pulp 40 % + Jaggery 60 %) (-2.93) and T_7 (Wood apple fruit Pulp 45 % + Jaggery 55 %) (-2.87). In the present experiment *b** value decreased with the increased levels of sugar and jaggery to the wood apple pulp. The lowest *b** value was observed in treatment T_4 (-1.96) this might be due to the fact that wood apple pulp contains natural carotenoids (yellow pigments). When jaggery is added, these are diluted or masked by darker compounds, thus lowering *b** reduced. Further, during drying, reducing sugars in jaggery undergo non-enzymatic browning, producing red-brown compounds that shift colour away from yellow. However, these reduction in *b** value did not significantly affect the sensory qualities of the wood apple fruit leather. Similar observations were also recorded by Kumar *et al.* (2017) while studying the effect of sugar acid ratio in stability of papaya and guava fruit leather and

Arinzechukwu and Nkama (2019) in the preparation of banana and cashew fruit leather.

Chemical parameters of wood apple fruit leather

The data with respect to effect of different ingredients on TSS, reducing sugars, non-reducing sugars and total sugar content in wood apple fruit leather was given in table 2.

TSS and sugars in fruit leather influence the sweetness, texture, shelf life and nutritional quality. Among the treatments, maximum total soluble solid content was observed in T_6 (Wood apple fruit pulp 40 % + Jaggery 60 %) (66.95 °Brix), which was closely followed by T_1 (Wood apple fruit pulp 40 % + Sugar 60 %) (65.83 °Brix) and the minimum total soluble solid content was recorded in the T_5 (Wood apple fruit pulp 60 % + Sugar 40 %) is 61.02 °Brix. The highest TSS content in the present experiment was achieved in the treatment T_6 (Wood apple pulp 40 % +Jaggery 60 %) (66.95°Brix) and followed by T_1(Wood apple pulp 40 % +sugar 60 %) (65.83°Brix), mainly due to the direct influence of solids present in the fruit pulp and the TSS content contributed by higher concentrations of jaggery. (It was also observed that TSS content of jaggery based fruit leather was more compared to sugar-based fruit leather which might be because jaggery contains minerals, acids and soluble organic matter in addition to sucrose all contribute to TSS measurement whereas refined sugar contributes to only sucrose. The reasons are comparable with the findings of Singh (2012) in guava and papaya leather incorporated with jaggery.

There was no significant difference was noticed with respect to reducing sugar content, T_6 treatment (Wood apple fruit pulp 40 % + Jaggery 60 %) recorded the maximum value of 4.11 per cent, while treatment T_5 (Wood apple fruit pulp 60 % + Sugar 40 %) had the minimum value of 3.94 per cent. But the results did not vary significantly among the treatments and that of in non-reducing sugar the maximum content was registered in T_1 (Wood apple fruit pulp 40 % + Sugar 60 %) (62.86 %) and the minimum non-reducing sugar content was observed in T_{10} (Wood apple fruit Pulp 60 % + Jaggery 40 %) is 62.70 per cent. In the present study, no significant differences were observed in the reducing sugar and non-reducing sugar content of fruit leather prepared with sugar and jaggery (Table 2). This could be due to the fact that both sugar and jaggery are composed of sucrose which undergoes partial hydrolysis during heating and drying process. As a result, the formation of reducing sugars occur in both treatment at nearly similar levels. Moreover, the fruit pulp itself contributes natural reducing sugars, thereby masking the variation that might arise from the sweetener type. Similar observations were recorded by Singh and Tiwari (2019) in guava and papaya leather, where incorporation of jaggery did not significantly alter the reducing sugar content when compared to sugar.

Table 2 : Effect of ingredients on total soluble solids and sugar content of wood apple fruit leather.

Treatment details	Total Soluble Solids (°Brix)	Reducing Sugars (%)	Non reducing Sugars (%)	Total Sugars (%)	Carbohydrates (%)
T_1	65.83[b]	4.08	62.86	66.94[a]	65.14[a]
T_2	63.57[e]	4.03	62.83	66.86[abc]	65.09[a]
T_3	62.41[g]	3.99	62.80	66.79[abcd]	64.21[b]
T_4	61.87[h]	3.96	62.77	66.73[cd]	64.08[b]
T_5	61.02[i]	3.94	62.74	66.68[d]	63.52[c]
T_6	66.95[a]	4.11	62.82	66.93[ab]	65.11[a]
T_7	65.58[c]	4.07	62.78	66.85[abc]	64.22[b]
T_8	64.63[d]	4.04	62.74	66.78[bcd]	64.10[b]
T_9	63.71[e]	4.02	62.72	66.74[cd]	63.56[c]
T_{10}	62.94[f]	3.99	62.70	66.69[d]	63.28[d]
S.Em±	**0.06**	**0.03**	**0.04**	**0.06**	**0.07**
CD @ 1%	**0.19**	**NS**	**NS**	**0.19**	**0.21**

In relation to total sugar content, the significant differences were found to exist among the treatments. Significantly higher total sugar content was found in T_1 (Wood apple fruit pulp 40 % + Sugar 60 %) (66.94 %), which was statistically similar with T_6 (Wood apple fruit pulp 40 % + Jaggery 60 %) (66.93 %), T_2 (Wood apple fruit Pulp 45 % + Sugar 55 %) (66.86 %), T_7 (Wood apple fruit Pulp 45 % + Jaggery 55 %) (66.85 %), T_3 (Wood apple fruit Pulp 50 % + Sugar 50 %) (66.79 %) and T_8 (Wood apple fruit Pulp 50 % + Jaggery (50 %) (66.78 %). The treatment T_{10} (Wood apple fruit Pulp 60 % + Jaggery 40 %) recorded the minimum value of 66.69 per cent. The total sugar content was found be highest in the treatment T_1

(66.94) sugar based which were comparable with the total sugar content of T_6 (66.93) jaggery based treatments (Table 2). This could be influence of high sugar and jaggery concentrations in the above said treatments along with the natural sugar content of the wood apple pulp. These observations were lined with the findings of Sreemathi *et al.* (2008) in sapota and papaya leather, Sharma *et al.* (2013) in wild apricot leather.

For carbohydrate content, significantly higher values were recorded in T_1 (65.14 %), which was statistically similar with T_6 (65.11 %), T_2 (65.09 %) and the minimum carbohydrate content was observed in T_{10} (63.28 %). The total carbohydrates influenced by more sugar concentration, that the higher values in certain treatments T_1 (65.14%) which was statistically on par with T_6 (65.11%) (Table 2). It might be attributed to added sweeteners and reduced moisture content by post-dehydration, as supported by Shaik (2018) in development and nutritional characterization of fortified guava fruit leather. Conversely, T_8 (63.28%) with lower carbohydrate levels likely reflect dilution effects from fiber-rich components or reduced sugar addition, similar to findings noted by Avhad *et al.* (2019) in studying the physicochemical and functional characterization of papaya and guava leathers.

Table 3 represents the influence of ingredients on chemical composition of wood apple fruit leather. Proper titratable acidity ensures refreshing flavour rather than being overly sweet or blend and is useful for standardizing the formulations. No significant variation was observed across all the treatments. In the present investigation, the lowest titratable acidity value was observed in T_6 (Wood apple fruit pulp 40 % + Jaggery 60 %) (2.14 %), while T_5 (Wood apple fruit pulp 60 % + Sugar 40 %) treatment recorded the highest titratable acidity value of 2.26 per cent. There was no significant difference was noticed among all treatments. With respect to the lowest titratable acidity recorded in T_6 (2.14 %) and T_1 (2.15 %) because the less pulp content and more jaggery concentration leads to reduction in acidity may be attributed to the inherent composition of jaggery which contains appreciable amounts of minerals such as potassium calcium and magnesium that act as natural buffers thereby neutralizes the fruit acids. Moreover, jaggery contribute to additional soluble solids as mentioned in reducing sugar which dilute the organic acids leading to reduced titratable acidity. Similar findings were reported by Supritha *et al.* (2018) in guava and papaya leather blended with sweet potato and soya slurry.

Concurrently the highest ascorbic acid content noticed in T_{10} (Wood apple fruit Pulp 60 % + Jaggery 40 %) (17.36 mg 100 g^{-1}), which was showed statistical parity with T_5 (Wood apple fruit pulp 60 % + Sugar 40 %) (17.31 mg 100g^{-1}) and the lowest ascorbic acid content was observed in T_1 (16.62 mg 100g^{-1}). The formulations with higher fruit concentration retained more ascorbic acid, likely due to reduced dilution and better matrix stability. The use of jaggery in wood apple fruit leather formulations significantly enhanced ascorbic acid retention compared to sugar-based treatments. The highest ascorbic acid content recorded in T_{10} (17.36 mg / 100g), this can be attributed to highest pulp and jaggery content (Table 3). Jaggery's natural antioxidant content and mineral profile, which collectively reduce oxidative degradation during drying similar findings reported by Singh and Tiwari (2019) in development of nutritious fruit leather by blending guava and papaya. The lowest ascorbic acid content observed in T_1 (16.62 mg / 100g) because refined sugar, lacking these protective compounds, offers no such buffering effect. These findings were comparable with Narayana *et al.* (2007) on comparative effect of different sugars instigating non-enzymatic browning and maillard reaction products in banana fruit leather.

Phenolic compounds contribute to astringency, bitterness and add characteristic flavour to the fruit leather. Apart from that, phenolic compounds and antioxidants possess nutritional and health benefits. The results of the present experiment revealed that the treatment T_{10} contained the maximum total phenolic content (184.99 mg GAE 100 g^{-1}) which was on par with T_9 (184.97 mg GAE 100 g^{-1}), T_8 (184.94 mg GAE 100 g^{-1}), T_7 (184.93 mg GAE 100 g^{-1}), T_6 (184.91 mg GAE 100 g^{-1}) whereas, the minimum total phenolic content was observed in T_1 (172.49 mg GAE 100 g^{-1}). The total phenols content in wood apple fruit leather, jaggery-based formulations with higher proportion of pulp retained highest levels of polyphenols activity of T_{10} (184.99 mg GAE / 100g) compared to sugar-based ones, this was because jaggery undergoes minimal refining by preserving its bioactive compounds, unlike refined sugar which was stripped of such nutrients, similar results found in Ho *et al.* (2018) in the development and nutritional characterization of fortified mixed fruit leather. The lowest phenol content recorded in sugar-based treatment T_1 (172.49 mg GAE/ 100g) because the refined sugar while enhancing sweetness, does not contribute any phenolic compounds. In fact, it may dilute the concentration of phenolics per unit mass of the product similar findings was observed in Anitha *et al.* (2016) development of value-added wood apple leather and its nutrient composition.

Table 3 : Effect of ingredients on chemical composition of wood apple fruit leather

Treatment details	Titratable acidity (%)	Ascorbic acid (mg 100g^{-1})	Total Phenols content (mg GAE 100g^{-1})	Total antioxidant activity (mg AAE 100g^{-1})	Fiber (%)
T_1	2.15	16.62^{e}	172.49^{d}	69.35^{d}	4.97^{e}
T_2	2.18	16.70^{de}	172.57^{d}	69.41^{cd}	5.02^{de}
T_3	2.20	16.82^{d}	172.64^{cd}	69.48^{b}	5.09^{bcde}
T_4	2.23	17.02^{bc}	172.75^{bc}	69.53^{bc}	5.14^{bcd}
T_5	2.26	17.31^{a}	172.81^{b}	69.59^{b}	5.21^{abc}
T_6	2.14	16.65^{e}	184.91^{a}	74.87^{a}	5.05^{cde}
T_7	2.17	16.82^{d}	184.93^{a}	74.90^{a}	5.10^{bcde}
T_8	2.19	16.98^{c}	184.94^{a}	74.93^{a}	5.17^{abcd}
T_9	2.21	17.12^{b}	184.97^{a}	74.96^{a}	5.23^{ab}
T_{10}	2.24	17.36^{a}	184.99^{a}	74.99^{a}	5.31^{a}
S.Em±	**0.02**	**0.06**	**0.06**	**0.07**	**0.07**
CD @ 1%	**NS**	**0.19**	**0.18**	**0.21**	**0.22**

The highest antioxidant activity was obtained in T_{10} (74.99 mg AAE 100 g^{-1}), which was statistically comparable with T_9 (74.96 mg AAE 100 g^{-1}), T_8 (74.93 mg AAE 100 g^{-1}), T_7 (74.90 mg AAE 100 g^{-1}) and T_6 (74.87 mg AAE 100 g^{-1}). Whereas, the lowest antioxidant activity was recorded in T_1 (Wood apple fruit pulp 40 % + Sugar 60 %) is 69.35 mg AAE 100 g^{-1}. The total antioxidant activity (TAA) in wood apple fruit leather, in the study demonstrated that highest TAA was observed in highest pulp and jaggery based treatment T_{10} (74.99 mg AAE/ 100g) which was statistically on par with T_6, T_7, T_8 and T_9 (Table 3). It was because wood apple is rich source of phenolic compounds, flavonoids and coumarins which enhance the natural antioxidant activity and similarly jaggery contribute to antioxidant activity similar and jaggery blending activity showed highest TAA in fruit leather observed in Mphaphuli *et al.* (2020) in enrichment of mango fruit leathers with natal plum improves their phytochemical content and antioxidant properties. In contrast, less pulp and more sugar concentration treatment T_1 (69.35 mg AAE / 100g) showed lowest TAA in fruit leather because refined sugar leads to free radical scavenging activity similar findings were recorded by Concha-Meyer *et al.* (2016) Strawberry and Kiwi leather.

The optimum fiber content is desirable in fruit leather as it helps in binding pulp solids giving the product a uniform chewy texture. For consumers it increases the functional food value by improving digestive health. The significantly highest fiber content was recorded in T_{10} (5.31 %), which was similar with T_9 (5.23 %), T_5 (5.21 %), T_8 (5.17 %), followed by T_7 (5.10 %) and T_6 (5.05 %), whereas the lowest fiber content was observed in T_1 (4.97 %). Fiber is an essential dietary component known to aid digestion and promote overall health. In wood apple fruit leather, the highest fiber content observed in T_{10} (5.31%) which was statistically similar with T_5, T_6, T_7, T_8 and T_9 (Table 2) because wood apple naturally contains fibers in it and jaggery is rich source of dietary fibers which leads to fiber rich fruit leather reported by Take *et al.* (2012) of physicochemical, nutritional and sensory attributes of high fiber fruit leather of sapota and papaya. The lowest fiber content observed in T_1 (4.97%) because less pulp content and increased sugar concentration in the formulation dilutes the fiber density which is in similar with the findings of Deepika *et al.* (2016) in development of Aonla fruit leather.

Organoleptic evaluation of wood apple fruit leather

Sensory evaluation in fruit leather gives an idea regarding how well the fruit leather is liked in terms of taste, texture, aroma, colour and overall appeal and it can be used to validate the instrumental findings. The effects of different ingredients of wood apple fruit leather on sensory evaluation is presented in Figure 1.

In the present study organoleptic evaluation score was statistically significant was noticed. The maximum colour score was obtained in T_6 (Wood apple fruit Pulp 40 % + Jaggery 60 %) (9.00), which was statistically similar with colour scores of T_1 (Wood apple fruit Pulp 40 % + Sugar 60 %) (8.50) and the minimum colour score was recorded in T_5 (Wood apple fruit Pulp 60 % + Sugar 40 %) (6.67). The colour of wood apple fruit leather was notably affected by sweetener type and pulp concentration. Jaggery-based treatment like T_6 (9.00) and sugar based treatment like T_1 (8.50) showed statistically higher appearance score. Deeper brown hues due to caramelized sugars and phenolic compounds, enhancing maillard reactions reported by Narayan *et al.* (2007) in banana fruit leather. In contrast, sugar-based treatment T_5 (6.67) appeared lighter, lacking molasses and browning precursors. The higher pulp levels further reduced colour scores, leading to duller surfaces, as also observed by Kaushal *et al.* (2002) in Apple pomace fruit leather. Overall, jaggery significantly improved visual appeal over refined sugar.

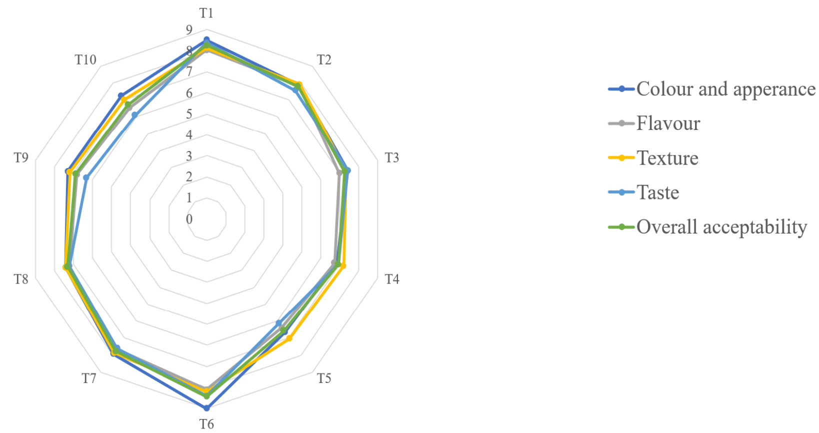

Fig. 1. Effect of varied concentration of ingredients on the organoleptic evaluation of wood apple fruit leather

T_1: Wood apple fruit Pulp (40 %) + Sugar (60 %)
T_2: Wood apple fruit Pulp (45 %) + Sugar (55 %)
T_3: Wood apple fruit Pulp (50 %) + Sugar (50 %)
T_4: Wood apple fruit Pulp (55 %) + Sugar (45 %)
T_5: Wood apple fruit Pulp (60 %) + Sugar (40 %)
T_6: Wood apple fruit Pulp (40 %) + Jaggery (60 %)
T_7: Wood apple fruit Pulp (45 %) + Jaggery (55 %)
T_8: Wood apple fruit Pulp (50 %) + Jaggery (50 %)
T_9: Wood apple fruit Pulp (55 %) + Jaggery (45 %)
T_{10}: Wood apple fruit Pulp (60 %) + Jaggery (40 %)

The highest flavour score was recorded in T_6 (8.10), which was statistically on par with T_1 (8.04) and the lowest flavour score was reported in T_5 (6.41). Jaggery-based treatment T_6 (8.10) achieved the highest flavour score, which was statistically similar with T_1 (8.04), owing to jaggery's caramelized nature and mineral-rich profile that complemented the tangy wood apple pulp and it might be due to sugar acid blend. Similarly, the flavour enhancement was reported by Yamini *et al.* (2015) in wood apple, where jaggery contributed depth and balance to the sensory matrix. In contrast, sugar-based treatments like T_5 (6.41) and T_{10} (6.54) showed flatter taste profiles due to the lack of flavour-enhancing compounds. Increasing pulp concentration intensified acidic and tannic nature, reducing flavour harmony, as also noted by Vinayaka (2019) in jamun fruit leather. Overall, jaggery proved superior in masking astringency and elevating flavour acceptability across fruit leather formulations.

The maximum texture score was obtained in T_6 (8.20), which was statistically comparable with texture scores of T_1 (8.13). and the minimum texture score was recorded in T_{10} (7.01). There was a statistically significant difference was found in texture score. In wood apple fruit leather treatments such as T_6 (8.20) and T_1 (8.13) achieved the highest texture scores, attributed to jaggery's natural binding agents and moisture-retaining properties that promote a smooth, pliable matrix. Similar improvements in texture were reported by Patel and Kulkarni (2017) in banana cactus mixed fruit leather, where jaggery enhanced flexibility and reduced brittleness. In contrast, sugar-based treatments like T_5 (7.03) and T_{10} (7.01) showed the lower scores due to refined sugar's lack of humectants, resulting in harder textures. Increased pulp concentration further contributed to roughness, as noted Vinayaka (2019) in jamun fruit leather.

The highest taste score was obtained in T_6 (8.40), which was on par with T_1 (8.37) and the lowest taste score was recorded in T_{10} (6.11). The taste contributed in wood apple fruit leather treatments such as T_6 (8.40) and T_1 (8.37) recorded the statistically highest taste scores, attributed to jaggery's rich flavor profile and synergistic interaction with wood apple pulp. Kulshrestha *et al.* (2012) observed similar enhancement in papaya fruit leather, where jaggery improved sweetness balance and masked astringency, yielding scores above 8.20. In wood apple fruit sheets, Yamini *et al.* (2015) reported taste scores of 8.10, citing jaggery's ability to mellow sourness and enrich mouthfeel. Likewise, Singh *et al.* (2003) noted improved taste in mango leather (score: 8.30) due to jaggery's caramel nature and mineral content. In contrast, sugar-based treatments like T_5 (6.14) and T_{10}

(6.11) showed lower scores, similar findings by Vinayaka (2019) in jamun leather, where refined sugar failed to harmonize with acidic pulp, resulting in taste scores below 6.30.

In terms of overall acceptability, maximum overall acceptability score was obtained in T_6 (8.42), which was followed by T_1 (8.26) and significantly the minimum overall acceptability score was recorded in T_5 (6.56) (Figure 1). The treatments such as T_6 (8.42) and T_1 (8.26) showed the highest overall acceptability, attributed to their balanced integration of colour, flavour, texture and taste. Gowda *et al.* (2019) reported similar findings in mango fruit leather, where jaggery-enhanced formulations scored above 8.30 for overall appeal. In Jamun bars, Sood and Bandral (2015) observed improved consumer satisfaction due to jaggery's rich sensory profile and cohesive texture. Conversely, sugar-based treatments like T_5 (6.56) recorded lower scores, findings from Vinayaka (2019) in jamun leather, where refined sugar failed to balance pulp acidity. These studies confirm jaggery's superior role in enhancing overall acceptability across diverse fruit leather products.

Conclusion

Among ten treatments, T_6 (Wood apple fruit Pulp 40 % + Jaggery 60 %) recorded the most desirable physical parameters with the maximum leather recovery percentage (81.46 %), colour values L^* (29.72), a^* (5.83), b^* (-2.93) and total soluble solids (66.95 °Brix), total sugars (66.93 %), carbohydrate (65.11%), along with superior chemical composition comprising ascorbic acid (16.65 mg/100g), total phenols content (184.91mg GAE / 100g), total antioxidant activity (74.87 mg AAE / 100g), fiber (5.05%) compared with T_1.The highest sensory evaluation scores observed in jaggery based treatment T_6 with colour (9.00), flavour (8.10), texture (8.20), taste (8.40), overall acceptability (8.42) in comparison to the conventional sugar based treatment T_1.

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