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Effect of fruit pulp and sugar concentration on the physicochemical, phytochemical and sensory characteristics of star fruit (*Averrhoa carambola*) leather

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Abstract. Starfruit is an underutilized fruit and is rich in vitamin C. Fruit leather from starfruit was prepared in this study and analyses of its physicochemical, phytochemical, and sensory characteristics were performed. Five samples named A, B, C, D and E were prepared with different proportions of fruit pulp:sugar of 70:30, 75:25, 80:20, 85:15 and 90:10, respectively. All the prepared samples were subjected to analyses. Phytochemical contents were found to increase with increasing fruit pulp proportion, thus sample E (90:10) was found to be the best in terms of phytochemical content. Similarly, product sample C (80:20) was scored the highest by the panelist in terms of sensory aspect. The best product sample C had total soluble solids (TSS) of 31 ± 2 °Bx, total ash content of 2.482 ± 0.001 %, acid insoluble ash of 1.0013 ± 0.002 %, crude protein of 0.5902 ± 0.004 %, crude fat of 0.3514 ± 0.003 %, crude fiber of 0.8991 ± 0.003 %, carbohydrate of 95.67 ± 0.04 %, vitamin C of 24.24 ± 0.1 mg/100g, total energy of 338.11 ± 0.04 Kcal/100 g, total phenolic content (TPC) of 6.105 ± 0.001 mg GAE/g of dry extract, total flavonoid content (TFC) of 1.125 ± 0.002 mg QE/g of dry extract and DPPH scavenging activity of 27.268 ± 0.001 %. Panelists responded favorably to the prepared product samples.

Keywords: Star fruit, phytochemical, fruit leather, sensory evaluation.

Classification numbers: 1.2.1, 1.3.1.

1. INTRODUCTION

Starfruit (*Averrhoa carambola* L.) is a fruit which is widely cultivated in northern part of South America, southern part of China, Southeast Asia, and India [1]. The term “carambola” comes from the word in Sanskrit, "*karmaranga*", which referred to as food appetizer [2]. This fruit has a deep golden appearance and distinctive star shape. At different stages of maturation, considerable changes in the composition of the fruit are observed [3]. The taste is sweet, a little tangy, and acidic with a fleshy, juicy, and crisp texture [4]. It is widely accepted to have strong

antioxidant properties which effectively scavenge free radicals and also help in the treatment of hypocholesterolemia and hypoglycemic [4].

One of the crucial steps in food preservation is drying. Fruit leather can be defined as a sweet and chewy product of dried fruits. It is prepared by spreading fruit pulp on a flat surface for drying. The fruit is taken or scraped off the surface after drying and rolled. When the fruit pulp is dried, it becomes shiny and has a leather-like texture, resulting to the name 'leather'. It does not require refrigeration storage and often has a long shelf-life [5]. Fruit leathers made from fruit pulp are appealing to the consumers and rich in nutrition. They are chewy or flexible strips with rich fruit flavors and contain a significant amount of nutrients of the fruit used [6]. Fruit-based leather is also listed in the traditional food list of Nepal. Traditional food can be defined as items passed to us from generations and involves utilization of simple foods which are economical and easily available in local region [7].

The value of this tropical fruit because of its high nutrient values and exotic appeal, is growing in developed nations [8]. Due to the higher risk of spoilage and high moisture level, starfruit has a restricted marketability resulting to significant postharvest losses [9]. It is preferred by public because of its sour and sweet taste, and it also has a high amount of antioxidants [9]. The shelf-life of star fruit is only a few weeks just before it is fully ruined by mold [10]. Preparation of fruit-based products from fruits with higher level of moisture could result in longer shelf-life of the fruits used [11]. Fruit-based products can be prepared from fruits having higher moisture content as reported in some previous research works [10, 12-16]. Limited studies have been conducted on starfruit leather. Therefore, this study was performed to present the nutritional values of starfruit leather and to introduce this product to consumers. The physicochemical and phytochemical values of star fruit pulp and prepared product samples were determined.

2. MATERIALS AND METHODS

2.1. Collection of raw materials

Starfruit and locally available table sugar were bought from the market of Urlabari (26°40′N 87°17′E). They were stored under refrigeration until preparation started. Ripe star fruit was used for the preparation of the product.

2.2. Preparation of fruit leather

The preparation of fruit leather was carried out using the method described in [17] with a few minor modifications (Figure 1).

Star fruit pulp and crystallized cane sugar as presented by Design Expert software were mixed uniformly for five different coded samples as shown in Table 1.

Table 1. Experimental design for the preparation of *star fruit leather* (per 100 g).

Sample	Star fruit pulp (parts)	Sugar (parts)
A	70	30
B	75	25
C	80	20
D	85	15
E	90	10

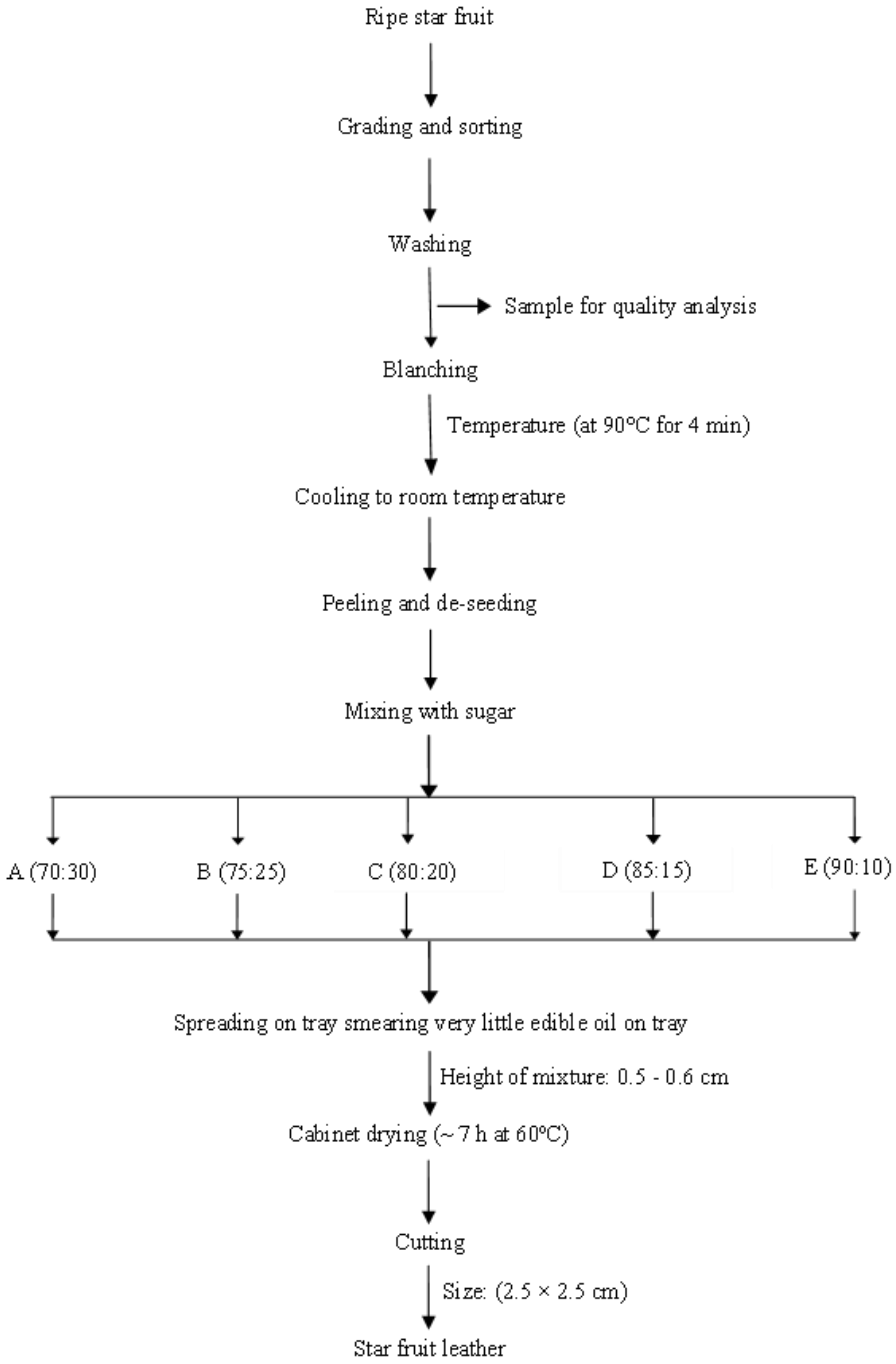

Figure 1. Preparation of star fruit leather.

2.3. Proximate and chemical analysis

The proximate values of the prepared samples were analyzed as described by [18] and the carbohydrate content was estimated using the difference method. The energy value was

calculated using the multiplication method and expressed as Kcal/100 g [19]. Ascorbic acid was determined as described by [20]. The reducing sugar was determined as described in [21].

2.4. Preparation of extract

Fresh star fruit pulp and star fruit leather were subjected to phytochemical extraction using methanol as described in [22].

2.5. Determination of total phenolic content

Total phenolic content (TPC) was determined using a spectrophotometer as mentioned by [23]. The concentration of gallic acid equivalent was expressed as: mg of GAE/g of dry extract.

2.6. Determination of DPPH radical scavenging activity

DPPH free radical scavenging activities (antioxidant activities) of extracts were determined using the method described by [24]. The percentage scavenging activity was determined according to the following equation:

$$\% \text{ scavenging activity} = (Ac\text{-}As) \times 100 / Ac$$

where: Ac = Absorbance of control; As = Absorbance of test sample; % scavenging activity = the total capacity of antioxidants for eliminating free radicals

2.7. Determination of total flavonoid content

Total flavonoid content was determined using a modified aluminum chloride assay method as described by [25]. The total flavonoid content is expressed as mg quercetin equivalents (QE) [25].

2.8. Sensory evaluation

Eight panelists of age group 22 - 39 (gender: 5 men and 3 women) selected from the students and teachers of Nilgiri College participated for evaluating the samples of star fruit leather using the 9-point hedonic rating test system as described by [18]. An evaluation card and 5 samples were provided to each panelist. They were provided with potable water for rinsing between the samples. Samples were served in clean plates and labeled with their respective codes. Sensory analysis was carried out in a room with proper lighting.

2.9. Statistical analysis

All the physicochemical and phytochemical data were collected in triplicate. Analysis of variance (ANOVA) and post-hoc test (Tukey) were carried out using GenStat Release 12.1, while graph construction and mean standard deviation calculation were performed using MS-Excel 2019.

3. RESULTS AND DISCUSSION

3.1. Quantitative analysis of physicochemical and phytochemical composition in star fruit pulp

The results of quantitative analysis of physicochemical and phytochemical composition in star fruit pulp are presented in Table 2.

Table 2. Quantitative analysis of physicochemical and phytochemical composition in star fruit pulp.

Parameter	**Result (wb)**
Moisture content (%)	88.68 ± 1.08
Acidity (as citric acid) (%)	0.61 ± 0.40
TSS (°Bx)	6.5 ± 0.5
pH	3.8 ± 0.09
Vitamin C content (mg/100 g)	30.68 ± 1
Crude protein (%)	0.82 ± 0.02
Crude fat (%)	0.4 ± 0.1
Crude fiber (%)	0.124 ± 0.01
Total ash content (%)	0.33 ± 0.2
Total carbohydrate (%)	9.646 ± 0.09
Total energy (Kcal/100g)	45.464 ± 4.75
Reducing sugar (%)	3.98 ± 0.02
DPPH radical scavenging activity (% of inhibition)	39.79 ± 0.04
Total phenolic content (mg GAE/g of dry extract)	7.89 ± 0.09
Total flavonoid content (mg QE/g of dry extract)	1.69 ± 0.04
Acid insoluble ash (%)	0.1132 ± 0.32

*Values are presented as mean ± standard deviation.

The moisture content was found to be 88.68 %, which was close to the values reported in [3] (89.66 %) and [26] (89.53 %), but lower than that recorded by [27] (91.4 %). TSS was found to be 6.5 %, greater than the values in some other studies [3, 26, 27]. The acidity was found to be 0.61 %, which was almost similar to that of [3] (0.36 %) and [26] (0.26 %). The pH value was found to be 3.8, which was similar to that of [26] (3.71), but slightly greater than in [27] (3.44). The crude protein was found to be 0.82 %, which was slightly greater than that recorded by [3] (0.43 %) and slightly less than that of [27] (1.01 %). The crude fat was found to be 0.4 %, which was slightly greater than that of [3] (0.32 %) and [27] (0.3 %). The crude fiber was found to be 0.124 %, which was slightly less than that recorded by [3] (0.96 %). The vitamin C content was found to be 30.68 mg/100 g, which was significantly greater than that given by [3] (23.4 mg/100 g) and significantly less than the values reported in [26] (35.41 mg/100 g) and [27] (34.4 mg/100 g). The carbohydrate was found to be 9.646 %, which was slightly greater than in [27] (6.73 %). The reducing sugar was found to be 3.98 %, which was lower than the values given by [26] (5.93 %) and [3] (5.04 %). The total ash was found to be 0.33 %, quite similar to the value of 0.32 % determined by [27]. The acid insoluble ash was found to be 0.1132 %, which was lesser than that of [28] i.e., 0.4 % in dry form.

The total phenolic content (TPC) was found to be 7.89 mg GAE/g of dry extract, which was slightly less than that in [29] i.e., 6.03 mg GAE/mL. The total flavonoid content (TFC) was found to be 1.69 mg QE/g of dry extract, which was slightly less than that in [29] i.e., 1.90 mg GAE/mL. The DPPH radical scavenging activity was found to be 39.79 % of inhibition, showing lower DPPH scavenging activity as compared to that reported in [29] with 37.82 % of inhibition.

3.2. Effect of variation of pulp and sugar on physiochemical and phytochemical properties of leather

The results obtained are presented in Table 3. Statistical analysis showed that there was significance effect ($p < 0.05$) of pulp on the crude fat, crude protein, crude fiber, total ash content, acid insoluble ash content, moisture content, total soluble solid (TSS), carbohydrate, vitamin C, total energy value, total phenolic content (TPC), total flavonoid content (TFC), DPPH scavenging activity of the samples at 5 % level of significance.

Table 3. Quantitative analysis of physicochemical and phytochemical composition of starfruit leather.

Sample	Crude fat (db %)	Crude protein (db %)	Crude fiber (db %)	Acid insoluble ash (db %)	Moisture content (wb %)
A	0.3151 ± 0.002^{a}	0.4845 ± 0.002^{a}	0.8008 ± 0.001^{a}	0.8891 ± 0.05^{a}	14.96 ± 0.08^{a}
B	0.3395 ± 0.005^{b}	0.5409 ± 0.010^{b}	0.8251 ± 0.001^{a}	0.9390 ± 0.007^{ab}	13.10 ± 0.06^{b}
C	0.3514 ± 0.003^{bc}	0.5902 ± 0.004^{bc}	0.8991 ± 0.003^{b}	1.0013 ± 0.002^{bc}	12.91 ± 0.03^{c}
D	0.3651 ± 0.010^{c}	0.6411 ± 0.003^{c}	0.9263 ± 0.002^{b}	1.0278 ± 0.001^{c}	12.34 ± 0.05^{d}
E	0.3909 ± 0.003^{d}	0.6871 ± 0.040^{d}	0.9687 ± 0.02^{c}	1.1039 ± 0.01^{d}	11.22 ± 0.02^{e}
Sample	**Total ash content (db%)**	**Carbohydrate (db %)**	**TSS (°Bx)**	**VitaminC (mg/100 g)**	**Energy (Kcal/100 g, wb)**
A	2.014 ± 0.004^{a}	96.38 ± 0.080^{a}	42 ± 1^{a}	21.05 ± 0.3^{a}	331.924 ± 0.05^{a}
B	2.060 ± 0.010^{b}	96.23 ± 0.090^{b}	36 ± 0^{b}	23.54 ± 0.2^{b}	339.047 ± 0.04^{b}
C	2.482 ± 0.001^{c}	95.67 ± 0.040^{c}	31 ± 2^{c}	24.24 ± 0.1^{c}	338.110 ± 0.04^{c}
D	2.764 ± 0.003^{d}	95.30 ± 0.070^{d}	24 ± 1^{d}	25.87 ± 0.1^{d}	339.300 ± 0.02^{d}
E	2.940 ± 0.030^{e}	95.01 ± 0.070^{e}	18 ± 0^{e}	27.58 ± 0.1^{e}	342.975 ± 0.08^{e}

Sample	DPPH (% of inhibition)	Total phenolic content (mg GAE/g of dry extract)	Total flavonoid content (mg QE/g of dry extract)
A	24.357 ± 0.002^{a}	5.167 ± 0.002^{a}	0.631 ± 0.002^{a}
B	26.932 ± 0.002^{b}	5.950 ± 0.020^{b}	0.925 ± 0.005^{b}
C	27.268 ± 0.001^{c}	6.105 ± 0.001^{c}	1.125 ± 0.002^{c}
D	30.861 ± 0.001^{e}	6.421 ± 0.004^{d}	1.436 ± 0.001^{d}
E	33.26 ± 0.02^{d}	6.89 ± 0.01^{e}	1.613 ± 0.002^{e}

*Values are presented as mean ± standard deviation. Values with different alphabets in a column are significantly different at $p < 0.05$.

Several studies reported that an increase in fruit pulp content resulted in an increase in crude fat, crude protein, crude fiber, total ash content, acid insoluble ash content, moisture content of the products [13, 14, 16], while in some other studies it was observed that total soluble solid (TSS), carbohydrate and total energy value increased with increasing sugar content [16, 30 - 33]. Here, the data also suggest the similar trend.

The results from [16] showed that there was an increase in vitamin C, DPPH scavenging activity, total flavonoid content and total phenolic content as the star fruit pulp increased. The phytochemicals can be lost during processing like drying and heat treatment. According to [30], the amount of vitamin C lost can be up to 10 - 60 % of the original amount of vitamin C in fruits and vegetables.

3.3. Sensory analysis of prepared star fruit leather

The sample products were subjected to sensory analysis (Figure 2). Statistical analysis showed that there was a significant effect ($p < 0.05$) of sample variations for sensory parameters other than flavour.

Among the 5 samples, sample C got the highest score but is not significantly different from samples A and B. The color can fade when dried in the sun due to direct exposure to air, but the appearance when dried in the oven may be affected by browning and caramelization of sugar at high temperatures [31]. Statistical analysis showed that there was no significant difference between samples A, B and D and between samples C and E for texture of prepared leather. The texture of the leather is dependent upon length of drying, humidity of air, sugar content, etc. Drying at low temperatures produces rubbery leather, while drying at high temperatures produces hard leather.

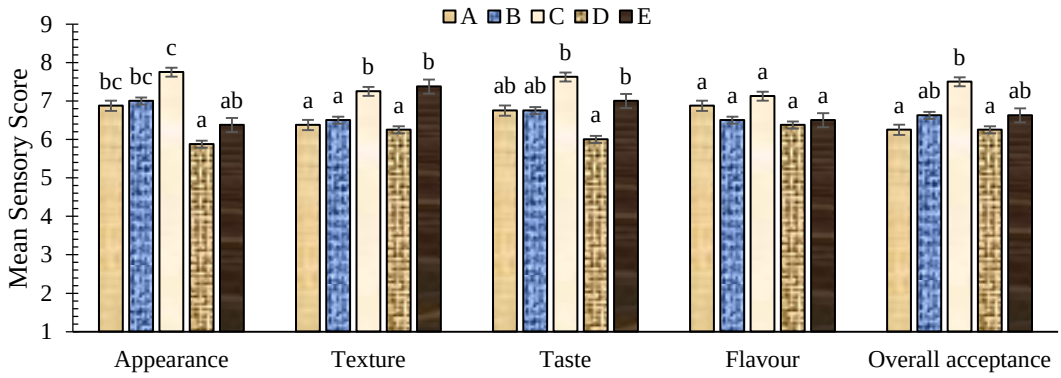

Figure 2. Mean sensory score of prepared five samples of star fruit leather. *Bars with different alphabets indicate significant difference ($p < 0.05$).

Sample C was highly favored by the panelists in terms of taste but was not significantly different from sample E. The amount of sugar directly affects the taste of fruit leather [32, 33]. There was no significant difference between the samples in terms of flavour. This suggests that the panelists found no significant difference in flavor with a 20 percent variation in sugar and fruit pulp. Overall acceptability was significantly affected by the sample variation. Sample C (80:20) scored the highest but was not significantly different from samples B and E. Since sample E had the highest phytochemical value and was not significantly different from sample C which scored highly for overall acceptability, taste, texture and flavour, we can take sample E (90:10) as the best sample among the formulations.

4. CONCLUSIONS

Star fruit leather prepared from 90 parts of pulp and 10 parts of sugar was found to be higher with respect to its physicochemical and phytochemical contents, and leather prepared from 80 parts of pulp and 20 parts of sugar was taken as the best sample according to sensory analysis among the prepared product samples. Fruit leather can be prepared using star fruit and the prepared product was found to be sensory-acceptable as well as having good nutritional value. Oxalic acid present in star fruit has been studied for having a negative impact when taken by consumers suffering from uremia [34]. Further study should be carried out to counter the

toxicity caused by consumption of this fruit. Different processes and their impact on toxins like caramboxin present in the fruit should be studied.

CRediT authorship contribution statement. Samiksha Gautam: Formal analysis, Methodology, Investigation, Revision of manuscript, Data analysis. Nabin Khadka: Resources, Methodology, Supervision, Final approval. Kishor Rai: Preparation of manuscript draft, Revision of manuscript.

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

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