

Comparative Study of Hybrid Dryer and Cabinet Dryer for Mixed Fruit Leather

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ABSTRACT

This research compares the effectiveness of cabinet dryer and hybrid dryer in the production of mixed fruit leather. The cabinet dryer provides a more conventional approach, but the hybrid dryer offers a unique drying method with energy-efficient heat transfer technology. For fruit leather, a popular snack made from fruit, to have the best texture, flavor, and shelf life, it needs to be dried under specific conditions. Fruit purees are combined with other ingredients to make mixed fruit leather, which is then dried under particular conditions. The panelists preferred the formulation of mixed fruit leather, which consisted of combining mango, kiwi, and dragon puree in a 50:25:25 ratio. The study looked at the proximate, physico-chemical and bioactive properties of mixed fruit leather that was dried using cabinet and hybrid dryers. It was found that the hybrid dryer retain more nutritional properties of mixed fruit leather than the cabinet dryer.

Keywords: Mixed Fruit Leather, Cabinet Dryer, Hybrid Dryer.

1. INTRODUCTION

Fruit leathers, also known as fruit bars, sheets, or rolls, are dehydrated fruit slabs with a chewy texture and sweet flavor. These low-moisture, dried fruit purée products are healthier alternatives for diabetics and health-conscious individuals due to their lower sugar content and emphasis on natural fruit flavors. The leathery texture is achieved through a combination of naturally occurring fruit acids and sugars, along with added humectants. Typically ranging from 8% to 15% in moisture content, fruit leathers concentrate the fruit's energy, vitamins, and minerals, making them a nutrient-rich snack (Diamante et al., 2014).

Fruit leathers' nutritional value is influenced by the source fruit and drying temperature. Higher temperatures and extended drying times result in a firmer texture, while the drying temperature and moisture content also affect the final texture. Fruit leather is used in various food products, including ice cream, biscuits, cakes, pastries, and breakfast cereals. The drying process can be achieved using methods like convection ovens, electric dehydrators, solar dryers, or direct sun drying. Fruits like papaya, mango, peaches, kiwifruit, and dragon fruit are suitable for fruit leather production. The resulting product has a shelf life of up to nine months (Bandaru and Bakshi, 2020).

The mango (*Mangifera indica* Linn.), known as the "King of Fruits," are known for their delicious taste and antioxidant properties. They are rich in polyphenols, gallic acid, vitamin C, and β -carotene, which may help prevent cancer and cardiovascular disease. However, due to their climacteric nature, mangoes face challenges in availability and pricing.

To preserve their health benefits, processed products like juice, bars, jams, jellies, powders, canned slices, purees, and leathers have been developed. Mango leather, particularly popular in India, is a dehydration process that transforms perishable mango pulp into shelf-stable leather or bars, ensuring long-term access to mangoes (Sarkar and Chakraborty, 2018).

The kiwi fruit (*Actinidia deliciosa*), is a berry with a distinctive greenish-brown skin and a firm, translucent green flesh with a sweet, unique flavor. It contains numerous tiny purple-black seeds and is rich in vitamin C, potassium, and folate. Kiwifruit consumption is associated with skin health and immune function, and it provides essential vitamins K, E, potassium, and folate. Dehydrated fruit snacks like kiwi fruit leather offer a chewy, portable snack with a sticky texture (Giacalone et al., 2019).

Dragon fruit (*Selenicereus undatus*), a rapidly growing superfood crop in India, is a tropical fruit from Central America and Mexico. Its vibrant color, distinctive shape, and potential health benefits have attracted global attention. The edible flesh, dotted with tiny black seeds, has high nutritional and economic value. The red-fleshed variety is particularly beneficial for water-soluble fiber, vitamin C, and proline. It also contains essential fatty acids, with linoleic acid accounting for 51%. Dragon fruit is used in various products, including leathers, ice creams, soft drinks, jams, jellies, and juices. The process involves pureeing the fruit flesh, adding natural flavors or sweeteners, and dehydrating it to create a chewy texture (Asabe et al., 2021).

Drying technology comes in four generations: first, second, third, and fourth. First-generation dryers are available in cabinet and bed types. Second-generation includes spray and drum dryers. Third-generation includes freeze dryers and osmotic dehydration. Fourth-generation dryers focus on physicochemical properties and nutrient retention, as customers seek nutrient-dense products for better health.

Drying is a process that removes water content from a substance, resulting in a solid product. Cabinet dryers are popular in the food industry due to their simplicity and cost-effectiveness. However, they can compromise the product's color, flavor, and nutritional value. Lower-temperature cabinet dryers offer lower capital investment and potentially minimize negative impacts on the final product (Darabi et al., 2015).

Hybrid drying technology is an alternative approach to fruit leather production, ensuring product temperature stays below 70°C to prevent direct contact with the heating medium. This indirect heating process preserves product quality and efficiency. Hybrid dryers produce high-quality dried or low-moisture products in various forms like powders, flakes, or sheets. Operating at low air pressure and temperature, they achieve energy-efficient heat transfer through a closed-loop system, recycling hot water for internal heating (Shende and Datta, 2019).

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Raw materials

Raw materials such as Mango, Kiwi, and Dragon fruits were sourced from the local market in Loni Kalbhor, Pune.

2.1.2 Chemicals

The analytical grade chemicals were made available in the Department of Food Chemistry and Nutrition Laboratory at the MIT School of Food Technology in Loni Kalbhor, Pune.

2.1.3 Processing equipment's

A hybrid dryer and a cabinet dryer were made accessible at the Department of Food Process and Product Engineering Laboratory, MIT School of Food Technology, Loni Kalbhor, Pune.

2.1.4 Analytical equipment's

The analytical equipment, including a weighing balance, desiccator, hot air oven, water bath, spectrophotometer, incubator, and autoclave, were provided by the MIT School of Food Technology in Loni Kalbhor, Pune.

2.2 Methods

2.2.1 Formulation and preparation of mixed fruit leather

The formulation of mixed fruit leather was standardized by modifying the quantity of mango pulp, kiwi pulp, and dragon fruit pulp with consistent amount of sugar as illustrated in Table 1.

Table 1. Formulation for preparation of mixed fruit leather Fresh mangoes, kiwis and dragon fruits were cleaned with water, then peeled and sliced into small pieces using a cutter. Pulping was carried out using a grinder. After calculating the weight of each pulp, the fruit purees were combined. Sugar was then added to the mixture. After that the mixture was placed on the trays, it was dried at 60 °C using a hybrid dryer and a cabinet dryer.

2.3 Proximate properties of mixed fruit pulp and leather

The A.O.A.C. (2005) method was used to assess the moisture content of mixed fruit pulp and leather. The technique according to Ranganna (1986) was used to calculate the sample's total ash content. The protein content of the end product and raw material was measured using the Kjeldhal equipment and the Kjeldhal method A.O.A.C. (2005). By employing the SOXLET apparatus and the A.O.A.C. (2005) method, the fat content was ascertained. Using FIBROTRON, the A.O.A.C. (2005) method was used to determine the fiber content. The total carbohydrate content was calculated using the A.O.A.C. (2005) technique.

2.4 Physico-chemical properties of mixed fruit pulp and leather

To determine the Total Soluble Solids (TSS) of mixed fruit pulp and leather, 1g of the samples were prepared and homogenized rapidly in 9ml of distilled water for a duration of one minute. After that, the filtrate was used for analysis. The sample's Total

Soluble Solid (TSS) content was determined using a portable refractometer (Erma hand refractometer). The pH was measured using the digital pH meter (pH-600). To assess the titratable acidity of the filtrates, 0.5 N NaOH was used for titration; the results were expressed as a percentage of the citric acid content. The Nelson-Somogyi approach was followed to determine the total and reducing sugars (Ranganna, 1986). By deducting reducing sugar from total sugar and increasing the result by a constant conversion ratio of 0.95, non-reducing sugar was calculated.

2.5 Bioactive properties of mixed fruit pulp and leather

The antioxidant activity, ascorbic acid content, and total phenol content of combined fruit pulp and leather were measured. Titration analysis was used to determine the vitamin C level (Thimmaiah 2016). According to Madalageri et al. (2015), the DPPH test was used to measure the antioxidant activity. The Folin-Ciocalteu colorimetric technique was used to determine the total phenol concentration (Cheng et al., 2013).

2.6 Sensory evaluation

A nine-point hedonic rating system was used to assess the mixed fruit sample's sensory qualities (1 being extremely disliked and 9 being extremely liked). In this study, the mixed fruit leather was judged using the scorecard proposed by Ranganna in 1986.

2.7 Statistical analysis

Sample analysis was performed in triplicate. The mean and standard deviation of the data were computed. Significant differences ($p < 0.05$) were determined using ANOVA single factor analysis.

3. RESULT AND DISCUSSION

3.1 Proximate analysis of mixed fruit pulp and leather

The data of proximate analysis of mixed fruit pulp and leather is displayed in Table 2. The analysis data shows moisture, ash, protein, fat, fiber and carbohydrate content of mixed fruit pulp and production of mixed fruit leather.

Samples	Mango pulp (g)	Kiwi pulp (g)	Dragon fruit pulp (g)	Sugar (g)
S1	50	25	25	10
S2	40	30	30	10
S3	30	35	35	10

Table 2. Proximate analysis of mixed fruit pulp and leather

Sr. No	Samples	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fiber (%)	Carbohydrate (%)
1	Mixed fruit pulp	62.58 ±0.06	0.51±0.03	0.60±0.03	0.41±0.01	0.78±0.01	33.12 ±0.75
2	Cabinet dried sample	18.67 ±0.08	1.96±0.01	1.57±0.30	1.55±0.01	1.85±0.01	74.40 ±0.01
3	Hybrid dried sample	15.21 ±0.23	2.10±0.01	2.93±0.04	2.09±0.02	2.51±0.03	75.16 ±0.02

(The values were mean ± standard deviation of three independent readings and within the column showed non-significance at $p > 0.05$ degree)

The quality of the raw materials significantly influences the final product's quality. The results are displayed in Table 2. Proximate analysis of mixed fruit pulp and leather results of the analysis of variance showed non-significance at $p > 0.05$ degree. Mixed fruit pulp has higher moisture content (62.58%) than cabinet dried mixed fruit leather (18.67%) and the drying time was 120±5.02 mins, and for hybrid dried mixed fruit leather (15.21%) and the drying time was 45±0.56 mins, according to the findings. Comparing the proximate composition of cabinet dried mixed fruit leather to that of mixed fruit pulp, there was a

notable increase in crude protein (1.57%), total fiber (1.85%), crude fat (1.55%), and carbohydrates (74.40%). Similar trends in increasing crude protein (2.93%), crude fat (2.09%), carbohydrate (75.16%), and total fiber (2.51%) were also observed in hybrid dried mixed fruit leather. After dehydration, nutrients become more concentrated, which increases the nutritious value of leather. (Kirby et al., 1991) and (Lynch et al., 2003) concur with the results.

3.2 Physico-chemical analysis of mixed fruit pulp and leather

Selective physico-chemical characteristics (pH, acidity, TSS and total sugar) of hybrid and cabinet-dried mixed fruit leather, as well as mixed fruit pulp, were evaluated; the findings are shown in the Table 3.

Table 3. Physico-chemical analysis of mixed fruit pulp and leather

(The values were mean ± standard deviation of three independent readings and within the column showed non-significance at p>0.05 degree)

The data in the table above, highlights notable differences in pH, acidity, total soluble solids (TSS), and total sugar concentration among the mixed fruit pulp and the cabinet dried and hybrid dried mixed fruit leather samples. Physico-chemical analysis of mixed fruit pulp and leather results of the analysis of variance showed non-significance at p>0.05 degree. Initially, the mixed fruit pulp exhibited the lowest pH value (3.95), indicative of its acidic nature. However, both cabinet dried and hybrid dried mixed fruit leather samples displayed slightly higher pH values (4.32 and 4.01, respectively), likely influenced by variations in the drying techniques employed. Acidity, a measure of acid content, was significantly higher in both cabinet dried (1.52%) and hybrid dried (1.48%) mixed fruit leather samples compared to the mixed fruit pulp (0.43%). TSS values, representing dissolved solids, were markedly elevated in the cabinet dried (45.5° Brix) and hybrid dried (47.0° Brix) mixed fruit leather samples compared to the mixed fruit pulp (18.0° Brix), indicating a concentration of soluble solids during the drying process. Moreover, the total sugar concentration in both cabinet dried (36.5%) and hybrid dried (39.7%) mixed fruit leather samples surpassed that of the mixed fruit pulp (8.5%), suggesting a concentration of sugars during drying. These findings align with previous research by (Singh et al., 2021).

3.3 Bioactive analysis of mixed fruit pulp and leather

The bioactive qualities of mixed fruit pulp and leather were examined, including antioxidant activity, ascorbic acid, and total phenol content. The results are shown in Table 4.

Table 4. Bioactive analysis of mixed fruit pulp and leather

Sr. No	Samples	Antioxidant (%)	Ascorbic acid (mg/100g)	Total Phenolic Content (mgGAE/g)
1	Mixed fruit pulp	85.46±1.16	83.85±0.13	10.76±0.42
2	Cabinet dried sample	38.28±0.01	36.05±0.06	4.51±0.01
3	Hybrid dried sample	56.58±0.01	54.80±0.00	7.74±0.01

(The values were mean ± standard deviation of three independent readings and within the column showed significance at p<0.05 degree)

Bioactive analysis of mixed fruit pulp and leather results of the analysis of variance revealed at significance at p<0.05

degree. The antioxidant activity, measured through DPPH scavenging activity, was notably high in the mixed fruit pulp, reaching 85.46%. Additionally, the hybrid drying method employed for the mixed fruit leather sample demonstrated increased DPPH inhibitory activity, recording 56.58%, compared to the cabinet drying method, which yielded 38.28%. This increased activity may be due to the higher total phenolic content (TPC) identified in the samples, which is consistent with prior research (Ndawula et al., 2004; Sogi et al., 2015). However, it is worth noting that the drying procedure resulted in a decrease in ascorbic acid content from 83.85 mg/100 g DW in the mixed fruit pulp to 54.80 mg/100 g DW after hybrid drying and 36.05 mg/100 g DW following cabinet drying. This drop is due to ascorbic acid oxidation caused by heat treatment during drying, which is consistent with earlier study (Nindo et al., 2003; Sogi et al., 2015). The TPC of mixed fruit leather

Sr. No	Samples	pH	Acidity (%)	TSS (°Brix)	Total Sugar (%)
1	Mixed fruit pulp	3.95±0.05	0.43±0.05	18.0±0.05	8.5±1.05
2	Cabinet dried sample	4.32±0.01	1.52±0.01	45.5±0.01	36.5±0.34
3	Hybrid dried sample	4.01±0.05	1.48±0.01	47.0±0.02	39.7±0.01

varied from 4.51 to 7.74 mg GAE/g DW, depending on the drying method used. Interestingly, hybrid drying had the highest TPC retention as compared to cabinet drying, presumably due to the infrared heat impact associated with the hybrid drying process, which drives the non-enzymatic transformation of phenolic precursors into new phenolic compounds (Nindo et al., 2003). Conversely, the lower TPC reported in cabinet dried mixed fruit leather could be ascribed to phenolic oxidation and heat-induced degradation during the drying process (Tontul and Topuz, 2017).

3.4 Sensory evaluation of mixed fruit leather

A semi-trained panelist used a 9-point hedonic scale to assess the organoleptic qualities of a mixed fruit leather sample. The results are displayed in Charts 1 and 2. According to the semi-trained panel members' sensory assessments, the formulation of S1 is well received.

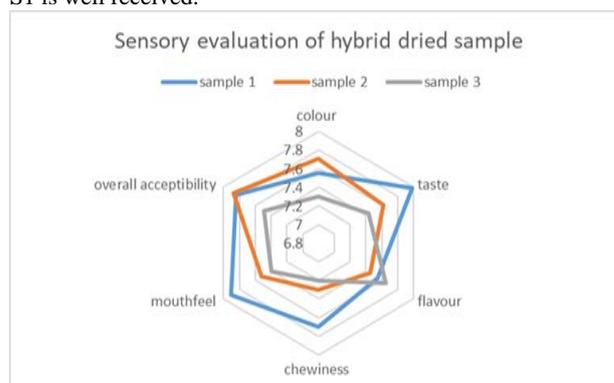


Chart 1. Graphical representation of sensory evaluation of hybrid dried mixed fruit leather

Based on the sensory evaluation of the hybrid dried samples, Sample 1 emerged as the most preferred sample. It received the highest scores in several key attributes: taste (7.8), chewiness (7.8), overall acceptability (7.8), and colour (7.6). Sample 1 also performed well in flavour (7.6) and mouthfeel (7.4). In comparison, Sample 2 had slightly lower scores, with taste (7.6), chewiness (7.0), overall acceptability (7.4), and colour (7.2). It matched Sample 1 in mouthfeel (7.4) but had a marginally lower flavour score (7.4). Sample 3 consistently scored the lowest, with taste (7.2), chewiness (6.8), overall acceptability (7.0), mouthfeel (7.2), flavour (7.6), and colour

(7.6). These results indicate that Sample 1 is the most favored due to its higher sensory scores across the board, while Sample 2 requires improvements in taste and overall acceptability to match Sample 1's level. Sample 3, being the least preferred, needs substantial enhancements to improve its sensory attributes and overall consumer preference. The results are associated with (Gupta et al., 2016).

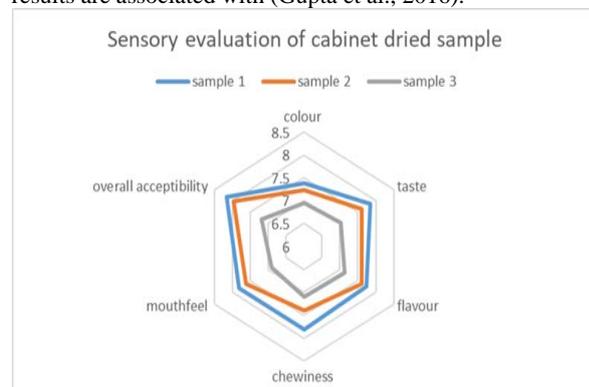


Chart 2. Graphical representation of sensory evaluation of cabinet dried mixed fruit leather.

Based on the sensory evaluation of the cabinet dried samples, Sample 1 emerged as the most preferred. It received the highest scores in taste (8.2), flavour (8.0), overall acceptability (8.0), and mouthfeel (7.4). It also scored well in colour (7.8) and chewiness (7.0). Sample 2 followed closely with scores of 8.0 in taste, 7.8 in flavour, 7.6 in overall acceptability, 7.2 in mouthfeel, and 7.8 in colour. However, its chewiness score was similar to Sample 1 at 7.0. Sample 3 was the least preferred, scoring 7.8 in taste, 7.6 in flavour, 7.2 in overall acceptability, 6.8 in mouthfeel, 6.5 in chewiness, and 7.5 in colour. These results highlight Sample 1 as the top candidate for consumer preference, while Sample 2 needs improvements in chewiness and mouthfeel, and Sample 3 requires substantial enhancements across various sensory attributes to match the levels of the other samples. The results are associated with (Gupta et al., 2016).

4. CONCLUSION

Mango, kiwi, and dragon fruit are all effective ingredients for producing mixed fruit leather. Utilizing these fruits during their peak seasons can also help in extending their shelf life. Mixed fruit leather retains a comparable nutritional value and is quite palatable. A novel drying technique, hybrid drying, has been found to consume less energy and time compared to traditional cabinet drying. This method maintains the natural and chemical properties of the mixed fruit leather, as it avoids the direct application of heat to the samples. The study observed that hybrid drying yields superior results compared to cabinet drying, making it the most suitable drying technology for producing mixed fruit leather.

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