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Effect of Drying Methods on the Organoleptic Properties and Water Activity of Mango Fruit Leather

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Abstract

Drying conditions can affect both consumer acceptance and water activity (aw), which influences fruit leather stability. This study compared direct sun drying, convection oven drying, and food dehydrator drying for Indramayu mango (Mangifera indica L.) fruit leather. A single-factor Completely Randomized Design was applied using three independent production replicates. Mango puree was dried under direct sunlight at approximately 35 °C for 8 h per day, in a convection oven at 50 °C for 9 h, or in a food dehydrator at 55 °C for 8 h. Sensory acceptance of color, aroma, texture, taste, and overall liking was evaluated by 48 untrained panelists using a 4-point hedonic scale. Water activity was measured in triplicate at 25 °C. Data were analyzed using one-way analysis of variance (ANOVA), followed by Duncan's multiple range test at $\alpha = 0.05$. The drying method significantly affected color ($F(2,141) = 18.29$, $p < 0.001$, $\eta^2 = 0.206$) and texture ($F(2,141) = 15.48$, $p < 0.001$, $\eta^2 = 0.180$), whereas aroma, taste, and overall acceptability did not differ significantly among treatments. The food dehydrator produced the highest scores for color and texture, while oven drying yielded the highest numerical taste score. Water activity also differed significantly among drying methods ($p < 0.001$), with sun drying producing the lowest value (0.520 ± 0.010). Overall, forced-air dehydration favored sensory quality, particularly color and texture, whereas sun drying achieved the lowest aw. These findings indicate that drying-method selection should be based on the intended balance between sensory quality and product stability.

Keywords: *Drying Method, Fruit Leather, Indramayu Mango, Sensory Evaluation, Water Activity.*

1. Introduction

Mango (*Mangifera indica* L.) is an economically important tropical fruit and a major raw material for fresh and processed products. Indramayu Regency, West Java, is widely recognized as a production center for local mangoes with a distinctive sweet flavor and soft flesh. Despite this potential, mango is highly perishable because of its high moisture content and active post-harvest metabolism. During peak harvest periods, rapid quality deterioration and market oversupply can reduce farm-gate value and increase food losses [1], [2]. Processing surplus fruit into stable, value-added products is therefore relevant for both post-harvest management and local agro-industry development [3].

Fruit leather is a thin, flexible sheet produced by concentrating and drying fruit puree, generally to an intermediate or low moisture state [4], [5]. The product is attractive for small-scale processing because it reduces product volume, extends usability, and can retain much of the fruit's characteristic flavor and color when the formulation and drying process are controlled. Drying is the critical unit operation because heat and mass transfer determine moisture removal, structure formation, pigment stability, volatile retention, and ultimately consumer acceptance [6], [8].

Three practical drying options are relevant for small and medium processors: direct sun drying, convection oven drying, and food dehydrator drying. Sun drying has low equipment and energy requirements, but the process is exposed to fluctuations in temperature, humidity, solar radiation, and contamination risk [8], [9]. Convection ovens provide more predictable thermal conditions, yet prolonged exposure to hot air can accelerate pigment degradation, volatile loss, and structural hardening [10]-[12]. Food dehydrators provide controlled temperature and continuous air circulation, which can improve drying uniformity and sensory consistency, although equipment and electricity costs are higher [13].

Previous research confirms that drying technology can alter sensory quality in mango products. Diop et al. [24] showed that drying conditions strongly affect mango color stability, while Bonneau et al. [31] demonstrated that drying modifies the volatile profile of mango. Mongi and Ngoma [35] also reported changes in sugar and organic acid profiles after solar drying. A direct comparison by Azeem et al. found that commercial dehydrator drying produced higher color, texture, flavor, appearance, and overall acceptance scores than oven and

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sun drying for Sindhri mango leather [47]. These findings indicate that drying effects are substantial, but they are not automatically transferable across cultivars, formulations, sheet thicknesses, and process temperatures.

Water activity (aw) is an equally important quality parameter because it describes the thermodynamic availability of water for microbial and chemical reactions. It differs from moisture content, which measures the total amount of water in a product. Fruit leathers commonly fall within an intermediate aw range, and values around or below 0.60 are generally associated with substantially restricted microbial growth [36]-[39]. However, aw alone does not establish shelf life. Storage stability also depends on pH, packaging barrier properties, oxygen exposure, storage temperature, and the presence of osmotolerant or xerophilic microorganisms [38], [41].

Previous studies have established that drying conditions influence mango color, volatile compounds, texture, moisture removal, and consumer response [24], [31], [35], [47], [49], [50]. Direct comparison remains difficult because cultivar, formulation, sheet thickness, dryer configuration, and drying endpoint vary substantially among studies. For Indramayu mango, evidence is still limited on how three accessible drying methods perform when sensory response and water activity are assessed together under the same formulation and production setting.

This study addresses that gap without duplicating the endpoints reported in a companion publication from the same research program. The companion paper examined proximate composition and antioxidant capacity under the same three drying regimes [46]. The present manuscript focuses on sensory acceptance and water activity. Examining these outcomes together adds a distinct process-selection perspective because a treatment that is preferred sensorially does not necessarily produce the lowest available-water level.

The objective was to determine the effect of direct sun drying, convection oven drying, and food dehydrator drying on the color, aroma, texture, taste, overall acceptability, and water activity of Indramayu mango fruit leather. We hypothesized that drying method would significantly influence sensory attributes and aw because each technique imposes a different thermal history and moisture-removal pattern. The comparison is intended for small-scale and community-based mango processing, where equipment cost, process control, hygiene, sensory quality, and product stability all influence technology choice. The results are therefore interpreted as a process-selection study within the tested formulation and operating conditions, not as a universal ranking of sun, oven, and dehydrator drying.

2. Methods

2.1. Time and location of the study

The study was conducted from April to September 2025 at the Family Resource Management Laboratory, Faculty of Engineering, Universitas Negeri Jakarta, and at laboratory facilities of IPB University, Indonesia.

2.2. Materials and equipment

The main raw material was fully ripe Indramayu mango (Mangifera indica L.) obtained from Indramayu Regency, West Java. Other formulation ingredients were sucrose, sorbitol, citric acid, gelatin, and water. The main processing equipment included a convection oven, food dehydrator, blender, hand mixer, digital balance, stainless-steel knife, saucepan, parchment paper, and drying trays. Water activity was measured using an AQUALAB Pawkit Water Activity Meter (METER Group, Inc., USA).

2.3. Experimental procedure

The experiment used a single-factor Completely Randomized Design with drying method as the factor. Three drying treatments were evaluated: A, direct sun drying; B, convection oven drying; and C, food dehydrator drying. Each treatment was prepared in three independent production replicates. The same mango fruit leather formulation was used for all treatments so that the drying method was the principal experimental difference. The formulation used for mango fruit leather production is presented in Table 1. Water served as the balancing component so that the complete formulation totaled 100%.

Table 1. Formulation of Mango Fruit Leather

Composition	Amount
Mango puree (%)	75.0
Sucrose (%)	10.0
Sorbitol (%)	5.0
Citric acid (%)	0.2
Gelatin (%)	0.6
Water (%)	9.2

2.4. Hedonic test

Sensory acceptance was evaluated by 48 untrained panelists. Each drying treatment therefore contributed 48 sensory observations for every hedonic attribute. Panelists assessed color, aroma, texture, taste, and overall acceptability using a 4-point hedonic scale, where 1 indicated the lowest degree of liking and 4 the highest. The same attributes and scoring scale were used for all treatments. Results are reported as mean ± standard deviation.

2.5. Water activity

Water activity (aw) was measured using an AQUALAB Pawkit Water Activity Meter (METER Group, Inc., Washington, DC, USA) following the measurement principles of ISO 18787:2017 [21]. Mango fruit leather samples were placed in clean sample cups and equilibrated at 25 °C for 1 h before measurement. Three measurements were obtained for each drying treatment, and results are reported as mean ± standard deviation.

2.6. Mango fruit leather preparation

Mango fruit leather was prepared using a modified fruit leather procedure [22] and process conditions aligned with the companion experiment from the same research program [46]. Mangoes were sorted, washed, peeled, and separated from the seed. The flesh was blended with water, sucrose, and sorbitol according to the formulation in Table 1. The mixture was heated at approximately 70 °C for 5-10 min. Citric acid and gelatin were then incorporated, and the puree was homogenized before being spread evenly on parchment-lined trays to a nominal thickness of approximately 3 mm. Three drying treatments were applied. Sun drying was carried out under direct sunlight at an ambient temperature of approximately 35 °C for about 8 h per day. Convection oven drying was conducted at 50 °C for 9 h, while food dehydrator drying was conducted at 55 °C for 8 h. Drying continued until the product formed a flexible, non-sticky sheet. Samples were cooled before water-activity measurement and sensory evaluation.

Table 2. Operational Drying Conditions Used for Mango Fruit Leather

Method	Temperature	Approx. duration	Heat/airflow environment	Drying endpoint
Sun drying	~35 °C ambient	~8 h/day	Direct sunlight; natural convection; weather-dependent	Flexible, non-sticky sheet
Convection oven	50 °C	9 h	Enclosed convection heating	Flexible, non-sticky sheet
Food dehydrator	55 °C	~8 h	Forced-air circulation	Flexible, non-sticky sheet

The puree layer was maintained at approximately 3 mm for all treatments. Oven and dehydrator temperatures were set before drying, whereas sun drying remained subject to natural variation in solar exposure and ambient conditions. The endpoint was a flexible, non-sticky sheet that could be removed from the tray without tearing. Relative humidity, solar irradiance, and air velocity were not continuously logged during sun drying; therefore, the stated temperature and exposure time describe the operating conditions rather than a fully controlled solar environment.

2.7. Statistical analysis

Data are reported as mean ± standard deviation. Differences among drying treatments were evaluated by one-way analysis of variance (ANOVA) at alpha = 0.05, followed by Duncan's multiple range test when the omnibus test was significant. The analysis followed the statistical framework used in the companion study [46]. Effect magnitude was summarized with eta squared ($\eta^2 = SS_{between}/SS_{total}$). Sensory analysis used 48 observations per treatment for each hedonic attribute, while water activity was measured from three production replicates per treatment. Statistical significance was set at $p < 0.05$. F statistics, degrees of freedom, p values, and η^2 are reported for the principal comparisons so that statistical significance and effect magnitude can be interpreted separately.

3. Results and Discussion

3.1. Sensory evaluation

The sensory results are summarized in Table 3. Drying method changed the perceived color and texture of Indramayu mango fruit leather, while aroma, taste, and overall acceptability remained statistically similar among treatments. The food dehydrator produced the highest mean color and texture scores, whereas oven drying produced the highest numerical taste score and sun drying produced the highest numerical aroma score.

The color score was 3.31 ± 0.67 for the dehydrator, 3.26 ± 0.69 for sun drying, and 2.51 ± 0.81 for oven drying. Thus, dehydrator and sun-dried samples were statistically similar for color, while both were preferred to the oven-dried sample. The result indicates that controlled moderate-temperature dehydration can preserve a bright and acceptable appearance, but direct sun drying under the conditions of this study also maintained color effectively.

Texture showed a similar treatment response. Dehydrator drying produced the highest mean score (3.26 ± 0.84), followed by oven drying (2.91 ± 0.81), while sun drying produced the lowest score (2.29 ± 0.94). The dehydrator and oven samples were statistically comparable, whereas the sun-dried product formed a less preferred texture. This pattern suggests that uniform heat and airflow improved the formation of a flexible, cohesive sheet.

For aroma, taste, and overall acceptability, the numerical differences did not reach statistical significance. Sun drying had the highest aroma score (2.69 ± 0.89), oven drying had the highest taste score (3.00 ± 0.99), and the dehydrator had the highest overall acceptability score (3.17 ± 0.65). These numerical rankings should therefore be interpreted as tendencies rather than proof that one method was superior for those attributes.

The ANOVA identified clear treatment effects for color, $F(2,141) = 18.29$, $p < 0.001$, $\eta^2 = 0.206$, and texture, $F(2,141) = 15.48$, $p < 0.001$, $\eta^2 = 0.180$. Aroma, $F(2,141) = 1.38$, $p = 0.255$, taste, $F(2,141) = 2.04$, $p = 0.134$, and overall acceptability, $F(2,141) = 2.71$, $p = 0.070$, were not significantly affected by drying method. Different superscript letters in Table 3 indicate significant differences according to Duncan's multiple range test at $p < 0.05$.

Table 3. Results of Organoleptic Evaluation of Mango Fruit Leather

Parameter	Dehydrator (n = 48)	Oven (n = 48)	Sun drying (n = 48)
Color	3.31 ± 0.67^{b}	2.51 ± 0.81^{a}	3.26 ± 0.69^{b}
Aroma	2.60 ± 0.93^{a}	2.40 ± 0.80^{a}	2.69 ± 0.89^{a}
Texture	3.26 ± 0.84^{b}	2.91 ± 0.81^{b}	2.29 ± 0.94^{a}
Taste	2.83 ± 0.91^{a}	3.00 ± 0.99^{a}	2.60 ± 1.02^{a}
Overall	3.17 ± 0.65^{a}	2.91 ± 0.73^{a}	2.86 ± 0.72^{a}

Values are mean ± standard deviation (n = 48 per treatment). Within each sensory attribute, means with different superscript letters differ significantly at $p < 0.05$ according to Duncan's multiple range test.

The color result is consistent with evidence that mango carotenoids and browning reactions are sensitive to thermal history and oxygen exposure [24], [25]. The lower oven color score may reflect longer exposure to convective heat at the product surface, which can promote non-enzymatic browning and pigment degradation. A recent systematic review of mango dehydration technologies also concluded that conventional hot-air processes can cause losses in color and other organoleptic attributes when temperature and residence time are not optimized [50].

The texture pattern agrees with Azeem et al. [47], who compared sun drying, hot-air oven drying, and commercial dehydrator drying for mango leather and reported the highest texture and overall sensory scores for the dehydrator. Their process used a higher dehydrator temperature of approximately 70 °C, while the present study used a milder temperature. Despite the different cultivar, formulation, scale, and hedonic instrument, both studies indicate that controlled airflow can improve texture consistency relative to direct sun drying.

Texture development in fruit leather depends on moisture gradients, sugar concentration, hydrocolloid behavior, and the rate at which the puree matrix passes from a viscous state to a flexible solid sheet. Irregular solar exposure can produce local differences in drying rate, resulting in regions that are either overly dry or sticky. In contrast, forced-air dehydration reduces spatial variability in heat and mass transfer, which supports a more uniform matrix [32], [49].

Aroma did not differ significantly among treatments, even though the sun-dried sample had the highest numerical score. Mango aroma is generated by a complex mixture of volatile compounds that can be lost or transformed during heating [27], [31]. The absence of a significant sensory difference suggests that, at the temperatures and times used here, changes in volatile composition were either limited or were not large enough to be distinguished reliably by untrained panelists using a 4-point scale.

Oven drying produced the highest numerical taste score, but the difference was not significant. Therefore, the present data do not support a claim that oven drying preserved sweetness better than the other methods. Changes in perceived taste after drying may involve sugar concentration, acidity, volatile loss, and matrix texture. Mongi and Ngoma [35] demonstrated that solar drying can alter sugar and organic-acid profiles in mango, which provides a plausible explanation for numerical differences across drying treatments.

The highest numerical overall acceptability score occurred in the dehydrator treatment, but overall liking did not differ significantly. This distinction is important for practical interpretation. The dehydrator clearly improved two attributes with significant treatment effects, color and texture, but the aggregate consumer response remained statistically comparable among the three methods. Product developers should therefore avoid describing the dehydrator as universally superior on the basis of overall liking alone.

Direct numerical comparison with earlier mango-leather studies should be made cautiously. Sensory scores depend on cultivar, ripeness, formulation, sugar and hydrocolloid levels, sheet thickness, dryer temperature, final moisture state, panel characteristics, and scale design [49]. The more informative comparison is the direction of the treatment effect. In this study, controlled forced-air drying improved color and texture relative to the tested alternatives, while the overall liking scores remained statistically similar.

From a process perspective, the sensory results favor the food dehydrator when visual appearance and texture consistency are the primary market requirements. Oven drying remains a feasible alternative because its texture score was not statistically different from the dehydrator, while its taste score was numerically highest. Sun drying is attractive for low energy input, but the lower texture score shows that low operating cost can be accompanied by less consistent sensory quality.

The sensory findings should be interpreted within the design limits. The panel was untrained and the 4-point scale intentionally forced a preference direction without a neutral midpoint. This approach is useful for screening consumer liking, but it provides less discrimination than longer hedonic scales and does not identify the specific descriptive attributes responsible for liking or disliking. A larger consumer panel and descriptive texture analysis would strengthen future product optimization.

Sensory quality alone, however, is insufficient for selecting a drying process. A product can be well liked while retaining enough available water to require more protective packaging or additional storage controls. For this reason, the sensory results were evaluated together with water activity.

3.2. Water activity and process trade-off

Water activity differed markedly among the three drying treatments. Sun drying produced the lowest mean aw, followed by the food dehydrator and the convection oven. This ranking shows that the drying method altered not only sensory quality but also the availability of water in the finished mango matrix.

The omnibus ANOVA was highly significant, $F(2,6) = 264.20$, $p < 0.001$, with a very large effect size ($\eta^2 = 0.989$). Duncan's multiple range test separated all three treatments. Mean aw was 0.520 ± 0.010 for sun drying, 0.623 ± 0.006 for dehydrator drying, and 0.653 ± 0.006 for oven drying.

The value of 0.520 for the sun-dried fruit leather is below the commonly cited aw threshold of 0.60 at which the growth of most bacteria, yeasts, and molds becomes strongly restricted [36]-[39]. In contrast, the dehydrator and oven products remained above 0.60. They should therefore not be described as shelf-stable solely on the basis of aw. Microbiological challenge or storage studies are required before making a shelf-life claim.

The individual measurements and treatment means are presented in Table 4.

Table 4. Water Activity (aw) Values of Mango Fruit Leather by Drying Method

Replication	Dehydrator	Convection oven	Sun drying
1	0.62	0.65	0.53
2	0.63	0.66	0.51
3	0.62	0.65	0.52
Average	0.623 ± 0.006^{b}	0.653 ± 0.006^{c}	0.520 ± 0.010^{a}

The water-activity ranking is consistent with the moisture-content pattern reported in the companion study from the same experimental program [46]. That study found the lowest moisture content after sun drying (12.71%), followed by food dehydrator drying (17.28%) and convection oven drying (19.42%). The parallel ranking of moisture content and aw strengthens the interpretation that the tested sun-drying condition removed water more extensively, although moisture content and aw describe different properties of the food matrix.

The result also provides a useful comparison with international fruit leather research. Chen et al. [48] reported aw values of approximately 0.60 to 0.64 in Burdekin plum leathers and demonstrated microbial stability during a six-month storage study. Their work is important because it shows that aw should be interpreted together with actual storage and microbiological data. The present study did not perform a storage challenge, so equivalent shelf-life performance cannot be assumed.

Earlier mango leather work reported that a combination of low aw, acidic pH, and appropriate packaging can support prolonged stability. However, the relationship is product-specific. Recent reviews place typical fruit leather aw across a relatively broad range and emphasize that formulation, soluble solids, hydrocolloids, drying endpoint, and packaging govern the final state [49]. The present values therefore fall within a plausible fruit leather range, but only the sun-dried treatment achieved aw below 0.60.

The drying parameters help explain the treatment ranking. Sun drying used a relatively low ambient temperature but a prolonged exposure period, allowing gradual diffusion of internal water toward the surface. The food dehydrator used 55 °C with forced air circulation, which provided more uniform heat and mass transfer but stopped at a higher aw. Oven drying at 50 °C produced the highest aw, suggesting that the applied time and airflow were not sufficient to remove as much available water as the other treatments under the tested sheet thickness.

Water activity must not be interpreted as identical to moisture content. Two products with similar total moisture can have different aw because sugars, acids, gelatin, and other solids bind water to different extents. Conversely, a lower moisture content often, but not always, corresponds to lower aw. Reporting both variables in related analyses is therefore more informative than using either parameter alone [38], [46].

The combined sensory and aw results reveal a practical trade-off. Sun drying produced the lowest aw but also the lowest texture score. The dehydrator produced the highest color and texture scores, yet its mean aw remained above 0.60. Greater water removal therefore did not correspond to greater sensory preference. This divergence is central to process selection because the preferred technology depends on whether the immediate target is consumer-facing quality, lower available water, or a balance of both.

For small-scale processors, sun drying may be attractive when energy cost is the dominant constraint and the process can be protected from dust, insects, and weather variation. Nevertheless, direct sun drying has weaker process control and higher hygiene risk than enclosed drying systems [9]. Its low aw result in this experiment should therefore be balanced against the need for sanitary handling and reproducible environmental conditions.

The food dehydrator offers a more controlled alternative. Its stable temperature and airflow support reproducible color and texture and reduce exposure to the external environment. To obtain an aw below 0.60, however, the drying endpoint may need optimization through longer drying time, adjusted temperature, lower sheet thickness, or a target aw-based termination criterion rather than a fixed process time.

The oven produced the highest aw and the lowest color score, indicating that the tested oven condition was not the optimal operating point for this formulation. Future optimization should examine temperature-time combinations, air velocity, tray loading, and sheet thickness. A process optimized only for drying time may not maximize either sensory quality or aw reduction.

Overall, the aw findings strengthen rather than replace the sensory results. A technically appropriate process should deliver acceptable consumer response and a validated stability target. For commercial application, the next step should combine aw with moisture content, pH, instrumental color and texture, microbial counts, packaging permeability, and real-time or accelerated shelf-life testing.

From an engineering perspective, the results show why drying method should not be interpreted only through nominal temperature. Direct solar exposure, convection heating, and forced-air dehydration impose different boundary conditions for heat and mass transfer. Air velocity, relative humidity, solar irradiance, tray loading, and exposed surface area can change the rate at which water migrates from the puree matrix even when drying time is similar. Consequently, the lower aw obtained by sun drying in this experiment should be interpreted as a result of the complete tested condition, not as evidence that sun drying is inherently superior for every production environment. Future optimization should record sample mass at regular intervals to generate drying curves and should continuously log air temperature, relative humidity, and air velocity. These data would permit calculation of drying rate, process efficiency, and a reproducible aw-based endpoint rather than reliance on fixed time alone [49], [50].

3.3. Practical implications, sustainability, and limitations

For the tested formulation, the food dehydrator is the stronger option when appearance, texture consistency, and process control are prioritized. Sun drying is attractive when low equipment energy and a lower aw are the main objectives, provided that sanitation and weather exposure can be controlled. The tested oven condition requires further optimization because it produced the lowest color score and the highest aw. These conclusions apply to the present operating conditions and should not be generalized to other mango cultivars, dryer designs, or batch scales without validation.

Effect sizes help distinguish meaningful treatment effects from small numerical differences. Drying method accounted for approximately 20.6% of the variance in color and 18.0% in texture, while the effects on aroma, taste, and overall acceptability were much smaller. The aw effect was substantially larger ($\eta^2 = 0.989$), showing that the drying treatment dominated the observed variation in available water within the three-replicate laboratory design. This large effect should not be extrapolated directly to different seasons, dryer capacities, formulations, or sheet thicknesses without validation.

Table 5. Decision-Oriented Comparison of the Tested Drying Methods

Method	Key sensory result	Mean aw	Practical advantage	Main limitation under tested conditions
Sun drying	Color 3.26; texture 2.29	0.520	Lowest aw and low direct equipment-energy demand	Weather dependence, lower texture score, and greater sanitation-control requirements
Convection oven	Color 2.51; texture 2.91	0.653	Enclosed and controllable heating environment	Highest aw and lowest color score; operating condition needs optimization
Food dehydrator	Color 3.31; texture 3.26	0.623	Best color and texture means with controlled airflow	aw remained above 0.60 at the tested endpoint; equipment and electricity required

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Table 5 summarizes the process trade-off without assigning a universal best method. The dehydrator provided the most favorable color and texture means under controlled airflow. Sun drying achieved the lowest aw but required greater control of environmental exposure and hygiene. The oven remained operationally simple, but its 50 °C, 9 h condition did not achieve the same color quality or aw reduction. Pilot-scale validation is needed before these laboratory findings are converted into commercial operating specifications.

From a sustainability perspective, converting surplus or cosmetically imperfect mango into fruit leather can reduce post-harvest losses and create a higher-value product with lower transport mass. This aligns most directly with SDG 12 on responsible consumption and production and may support local agro-processing. Nevertheless, a full sustainability claim requires energy, cost, yield, packaging, and loss-reduction data. Sun drying has low direct energy demand, whereas dehydrator and oven systems may offer better hygiene and process consistency at the expense of electricity use.

The study has four main limitations. First, relative humidity, solar irradiance, and air velocity were not continuously logged during sun drying. Second, the sensory evaluation used 48 untrained panelists and a 4-point hedonic scale, which is suitable for preference screening but offers less discrimination than longer consumer scales. Third, instrumental color and texture measurements were not included. Fourth, shelf life was not verified by microbiological challenge or storage testing. These limitations define the scope of inference and identify priorities for follow-up work.

Scale-up should focus on variables that control heat and mass transfer rather than reproducing laboratory drying time alone. Future experiments should record initial soluble solids, pH, puree mass per tray, sheet thickness, product temperature, inlet-air temperature and relative humidity, air velocity, periodic mass loss, final moisture content, and final aw. Drying curves would allow process rates to be compared across technologies. For oven and dehydrator systems, factorial or response-surface optimization of temperature and time could identify a condition that lowers aw while protecting color and texture. Shelf-life claims should then be validated using pH, moisture content, microbiological counts, packaging-barrier properties, and sensory quality during storage [38], [49], [50].

4. Conclusion

Drying method significantly affected the color, texture, and water activity of Indramayu mango fruit leather. The food dehydrator produced the highest mean color and texture scores, whereas sun drying produced the lowest aw (0.520 ± 0.010). Aroma, taste, and overall acceptability did not differ significantly among treatments. The results therefore do not support a single drying method as optimal for every quality target. Under the tested conditions, the dehydrator gave the most consistent sensory advantages for appearance and texture, while sun drying reduced available water more effectively. The water-activity pattern also agrees with the moisture-content ranking reported in the companion study [46]. Only the sun-dried treatment reached aw below 0.60; however, shelf-life claims still require microbiological validation, packaging assessment, and storage testing. Further optimization should target a controlled process that combines the sensory advantages of forced-air dehydration with an aw endpoint appropriate for the intended storage system.

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References

[1]. F. Awaliyah, B. R. Saefudin, L. Sulistyowati, E. Rasmikayati, and D. Dwirayani, “International Journal Agriculture and Environmental Research Mango Agribusiness Development In West Java Province, Indonesia 1* International Journal Agriculture and Environmental Research,” 2022, doi: 10.51193/IJAER.2022.8603.

[2]. M. A. Ullah, A. Khanal, P. Joyce, N. White, A. Macnish, and D. Joyce, “Internal Disorders of Mango Fruit and Their Management Physiology, Biochemistry, and Role of Mineral Nutrients,” Plants 2024, Vol. 13, Page 2596, vol. 13, no. 18, p. 2596, Sep. 2024, doi: 10.3390/PLANTS13182596.

[3]. W. O. Owino and J. L. Ambuko, “Mango Fruit Processing: Options for Small-Scale Processors in Developing Countries,” Agriculture 2021, Vol. 11, Page 1105, vol. 11, no. 11, p. 1105, Nov. 2021, doi: 10.3390/AGRICULTURE11111105.

[4]. P. D. Shere, A. A. Palve, and S. V. Ghodke, “Effect of Drying on Nutritional Profile of Fruit Leathers,” Journal of Advances in Food Science & Technology, vol. 10, no. 3, pp. 60–65, Aug. 2023, doi: 10.56557/JAFSAT/2023/V10I38343.

[5]. M. Kaur and P. Godara, “Various drying processes for fruit leathers preparation and its effects on quality of fruit leathers,” ~ 2099 ~ The Pharma Innovation Journal, vol. 11, no. 5, pp. 2099–2105, 2022, Accessed: Feb. 07, 2025. [Online]. Available: http://www.thepharmajournal.com

[6]. A. Shrivastava, M. K. Gaur, and P. Singh, “Mango leather (Aam Papad) drying in hybrid greenhouse solar dryer with evacuated tube collector and finned drying tray: drying behavior and economic analysis,” Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, Jan. 2022, doi: 10.1080/15567036.2022.2029974.

[7]. L. A. Adepoju and D. Osunde, “Effect of pretreatments and drying methods on some qualities of dried mango (Mangifera indica) fruit,” Agricultural Engineering International: CIGR Journal, vol. 19, no. 1, pp. 187–194, Jun. 2017, Accessed: Sep. 10, 2025. [Online]. Available: https://cigrjournal.org/index.php/Ejounral/article/view/3877

[8]. M. Radojčin et al., “Effect of Selected Drying Methods and Emerging Drying Intensification Technologies on the Quality of Dried Fruit: A Review,” Processes 2021, Vol. 9, Page 132, vol. 9, no. 1, p. 132, Jan. 2021, doi: 10.3390/PR9010132.

[9]. D. Alp and Ö. Bulantekin, “The microbiological quality of various foods dried by applying different drying methods: a review,” European Food Research and Technology, vol. 247, no. 6, pp. 1333–1343, Jun. 2021, doi: 10.1007/s00217-021-03731-z.

[10]. F. N. Akbar, S. Mahmood, G. Mueen-ud-din, M. Yamin, and M. A. Murtaza, “Exploring the Effects of Drying Method and Temperature on the Quality of Dried Basil (Ocimum basilicum L.) Leaves: A Sustainable and Eco-Friendly Drying Solution,” Resources 2024, Vol. 13, Page 121, vol. 13, no. 9, p. 121, Aug. 2024, doi: 10.3390/RESOURCES13090121.

[11]. H. Uslu Demir, D. Atalay, and H. S. Erge, “Kinetics of the changes in bio-active compounds, antioxidant capacity and color of Cornelian cherries dried at different temperatures,” Journal of Food Measurement and Characterization, vol. 13, no. 3, pp. 2032–2040, Sep. 2019, doi: 10.1007/s11694-019-00124-5.

[12]. R. ElGamal, C. Song, A. M. Rayan, C. Liu, S. Al-Rejaie, and G. ElMasry, "Thermal Degradation of Bioactive Compounds during Drying Process of Horticultural and Agronomic Products: A Comprehensive Overview," Agronomy 2023, Vol. 13, Page 1580, vol. 13, no. 6, p. 1580, Jun. 2023, doi: 10.3390/AGRONOMY13061580.
[13]. S. Madhankumar, K. S. R. Muthukkhumaran, R. A. Navaneeth, M. Padmanabhan, and K. M. Shriram, "Design and Modelling of Automated Hot Oven Food Dehydrator," 2021 7th International Conference on Advanced Computing and Communication Systems, ICACCS 2021, pp. 1130–1134, Mar. 2021, doi: 10.1109/ICACCS51430.2021.9441881.
[14]. S. Ray, "Sensory Properties of Foods and Their Measurement Methods," Techniques to Measure Food Safety and Quality: Microbial, Chemical, and Sensory, pp. 345–381, Sep. 2021, doi: 10.1007/978-3-030-68636-9_15.
[15]. L. Esposito et al., "Sensory Evaluation and Consumers' Acceptance of a Low Glycemic and Gluten-Free Carob-Based Bakery Product," Foods 2024, Vol. 13, Page 2815, vol. 13, no. 17, p. 2815, Sep. 2024, doi: 10.3390/FOODS13172815.
[16]. K. Sielatycka et al., "Application of flow cytometry and measurement of water activity to evaluate the stability of probiotic products," May 2023, doi: 10.21203/RS.3.RS-2909255/V1.
[17]. W. Y. Koh, P. Matanjun, X. X. Lim, and R. Kobun, "Sensory, Physicochemical, and Cooking Qualities of Instant Noodles Incorporated with Red Seaweed (Eucheuma denticulatum)," Foods, vol. 11, no. 17, p. 2669, Sep. 2022, doi: 10.3390/FOODS11172669.
[18]. M. G. O'Sullivan, "Sensory Affective (Hedonic) Testing," A Handbook for Sensory and Consumer-Driven New Product Development, pp. 39–57, Jan. 2017, doi: 10.1016/B978-0-08-100352-7.00003-8.
[19]. M. C. Meilgaard, B. T. Carr, and G. V. Civille, "Sensory Evaluation Techniques." Accessed: Apr. 19, 2025. [Online]. Available: https://books.google.co.id/books?id=F_A-YtWXF3gC&printsec=frontcover#v=onepage&q&f=false
[20]. K. Kajak-Siemaszko et al., "Effect of Lactic Acid Bacteria on Nutritional and Sensory Quality of Goat Organic Acid-Rennet Cheeses," Applied Sciences 2022, Vol. 12, Page 8855, vol. 12, no. 17, p. 8855, Sep. 2022, doi: 10.3390/APP12178855.
[21]. ISO-18787, "Foodstuffs-Determination of water activity Produits agricoles et alimentaires-Détermination de l'activité de l'eau," Switzerland, 2017. [Online]. Available: https://standards.iteh.ai/catalog/standards/sist/3d097d8f-650c-4eb7-80c5-
[22]. T. Mphaphuli, V. E. Manhivi, R. Slabbert, Y. Sultanbawa, and D. Sivakumar, "Enrichment of mango fruit leathers with natal plum (Carissa macrocarpa) improves their phytochemical content and antioxidant properties," Foods, vol. 9, no. 4, Apr. 2020, doi: 10.3390/foods9040431.
[23]. M. Truebner, "The Dynamics of 'Neither Agree Nor Disagree' Answers in Attitudinal Questions," J Surv Stat Methodol, vol. 9, no. 1, pp. 51–72, Jan. 2021, doi: 10.1093/JSSAM/SMZ029.
[24]. A. Diop et al., "Impact of Special Drying Schemes on Color Stability of Mangoes with Different Maturity Degrees," Foods, vol. 11, no. 5, Art. no. 656, Mar. 2022, doi: 10.3390/foods11050656.
[25]. U. R. Marin-Castro, P. Dominique, M. A. García-Alvarado, M. A. Vargas-Ortiz, M. A. Salgado-Cervantes, and A. Servent, "Effect of the thermal state during Manila mango processing by mild flash vacuum-expansion on carotenoids and enzymatic activity," Innovative Food Science & Emerging Technologies, vol. 75, p. 102900, Jan. 2022, doi: 10.1016/J.IFSET.2021.102900.
[26]. I. Moutia, E. Lakatos, and A. J. Kovács, "Impact of Dehydration Techniques on the Nutritional and Microbial Profiles of Dried Mushrooms," Foods 2024, Vol. 13, Page 3245, vol. 13, no. 20, p. 3245, Oct. 2024, doi: 10.3390/FOODS13203245.
[27]. H. Xie et al., "Effects of Volatile Flavour Compound Variations on the Varying Aroma of Mangoes 'Tainong' and 'Hongyu' during Storage," Molecules 2023, Vol. 28, Page 3693, vol. 28, no. 9, p. 3693, Apr. 2023, doi: 10.3390/MOLECULES28093693.
[28]. J. Ampah, K. A. Dzisi, A. Addo, and A. Bart-Plange, "Drying Kinetics and Chemical Properties of Mango," International Journal of Food Science, vol. 2022, Art. no. 6243228, 2022, doi: 10.1155/2022/6243228.
[29]. M. Castillo-Téllez et al., "Solar drying of oregano leaves (Plectranthus amboinicus, Lour): Analysis of experimental performance under a tropical climate," Energy Exploration & Exploitation, vol. 42, no. 5, pp. 1895–1921, Sep. 2024, doi: 10.1177/01445987241234389.
[30]. N. Cengiz, A. Abdulvahitoğlu, and A. Abdulvahitoğlu, "Comparative Analysis of Different Drying Methods on Strawberry Aroma Compounds via Multi-Criteria Decision-Making Techniques," Applied Sciences 2025, Vol. 15, Page 815, vol. 15, no. 2, p. 815, Jan. 2025, doi: 10.3390/APP15020815.
[31]. A. Bonneau, R. Boulanger, M. Lebrun, I. Maraval, and Z. Gunata, "Aroma compounds in fresh and dried mango fruit (Mangifera indica L. cv. Kent): impact of drying on volatile composition," Int J Food Sci Technol, vol. 51, no. 3, pp. 789–800, Feb. 2016, doi: 10.1111/IJFS.13038.
[32]. G. Senthilkumar, F. A. Rohit, M. A. Garwin, N. Joy, S. Ganesan, and J. Hemanandth, "Design and fabrication of dehydrator for vegetables and fruits," AIP Conf Proc, vol. 2311, no. 1, Dec. 2020, doi: 10.1063/5.0034133.
[33]. R. da Silva Simão, J. O. de Moraes, P. G. de Souza, B. A. M. Carciofi, and J. B. Laurindo, "Production of mango leathers by cast-tape drying: Product characteristics and sensory evaluation," LWT, vol. 99, pp. 445–452, 2019, doi: 10.1016/j.lwt.2018.10.013.
[34]. S. Ge et al., "Changes in volatile flavor compounds of peppers during hot air drying process based on headspace-gas chromatography-ion mobility spectrometry (HS-GC-IMS)," J Sci Food Agric, vol. 100, no. 7, pp. 3087–3098, May 2020, doi: 10.1002/JSFA.10341.
[35]. R. J. Mongi and S. J. Ngoma, "Effect of Solar Drying Methods on Proximate Composition, Sugar Profile and Organic Acids of Mango Varieties in Tanzania," Applied Food Research, vol. 2, no. 2, p. 100140, Dec. 2022, doi: 10.1016/J.AFRES.2022.100140.
[36]. A. Mason, M. Muradov, B. Abdullah, A. Al-Shamma'a, and O. Alvseike, "Rapid Non-Destructive Prediction of Water Activity in Dry-Cured Meat," Proceedings 2018, Vol. 2, Page 1003, vol. 2, no. 13, p. 1003, Nov. 2018, doi: 10.3390/PROCEEDINGS2131003.
[37]. V. Lima, C. A. Pinto, and J. A. Saraiva, "The dependence of microbial inactivation by emergent nonthermal processing technologies on pH and water activity," Innovative Food Science & Emerging Technologies, vol. 89, p. 103460, Oct. 2023, doi: 10.1016/J.IFSET.2023.103460.
[38]. M. Peleg, "Models of the water activity effect on microbial growth rate and initiation," Applied Microbiology and Biotechnology, vol. 106, no. 4, pp. 1375–1382, Feb. 2022, doi: 10.1007/s00253-022-11792-7.
[39]. U. Venkatesan and R. Muniyan, "Review on the extension of shelf life for fruits and vegetables using natural preservatives," Food Sci Biotechnol, vol. 33, no. 11, p. 2477, Aug. 2024, doi: 10.1007/S10068-024-01602-3.

[40]. S. Akther, A. Sultana, M. R. Badsha, M. M. Rahman, M. A. Alim, and A. M. Amin, "Physicochemical properties of mango (Amropali cultivar) powder and its reconstituted product as affected by drying methods," Int J Food Prop, vol. 23, no. 1, pp. 2201–2216, Jan. 2020, doi: 10.1080/10942912.2020.1849278.
[41]. J. E. Hallsworth, "Water is a preservative of microbes," Microbial Biotechnology, vol. 15, no. 1, pp. 191–214, Jan. 2022, doi: 10.1111/1751-7915.13980.
[42]. O. Nnamchi et al., "Solar dryers: A review of mechanism, methods and critical analysis of transport models applicable in solar drying of product," Green Energy and Resources, vol. 3, no. 2, p. 100118, Jun. 2025, doi: 10.1016/J.GERR.2025.100118.
[43]. C. Barrera, N. Betoret, and L. Seguí, "Potential of vacuum impregnation and osmotic dehydration techniques in producing jaggery-fortified apple snacks," Sustainable Food Technology, vol. 2, no. 4, pp. 1041–1051, Jul. 2024, doi: 10.1039/D3FB00255A.
[44]. M. S. Srinivas, S. K. Jain, N. K. Jain, S. S. Lakhawat, A. Kumar, and H. K. Jain, "A Review on the Preparation Method of Fruit Leathers," Int J Curr Microbiol Appl Sci, vol. 9, no. 5, pp. 773–778, May 2020, doi: 10.20546/ijcmas.2020.905.085.
[45]. M. Ali et al., "Global insights and advances in edible coatings or films toward quality maintenance and reduced postharvest losses of fruit and vegetables: An updated review," Compr Rev Food Sci Food Saf, vol. 24, no. 1, p. e70103, Jan. 2025, doi: 10.1111/1541-4337.70103.
[46]. R. Irwanto, Mulyati, J. Marsita, B. K. Jati, and N. Fatin, "Effect of Drying Methods on Indramayu Mango Leather Quality," Jurnal Ilmu Pangan dan Hasil Pertanian, vol. 10, no. 1, pp. 78-99, 2026, doi: 10.26877/jiphp.v10i1.760.
[47]. A. Azeem, A. A. Panhwar, P. Meghwar, A. Irshad, U. A. Soomro, and S. M. Zahra, "Effect of Various Drying and Dehydration Techniques on the Organoleptic Quality of Mango Leathers," RADS Journal of Biological Research & Applied Sciences, vol. 12, no. 1, pp. 66-74, 2021.
[48]. G. Chen, S. M. O. Mantilla, M. E. Netzel, D. Cozzolino, D. Sivakumar, and Y. Sultanbawa, "Physicochemical, antioxidant and microbial stability of Burdekin plum leathers," International Journal of Food Science & Technology, vol. 59, no. 4, pp. 2716-2726, 2024, doi: 10.1111/ijfs.17023.
[49]. K. L. Santos, B. Guevara-Guerrero, J. M. Lara Junior, P. H. M. de Sousa, and L. B. de Vasconcelos, "Recent Advances in Fruit Leather Development: A Review," Journal of Food Process Engineering, vol. 48, no. 11, e70254, 2025, doi: 10.1111/jfpe.70254.
[50]. L. C. López and G. A. Hincapié-Llanos, "Comparison of Mango (Mangifera indica) Dehydration Technologies: A Systematic Review," AgriEngineering, vol. 6, no. 3, pp. 2694-2717, 2024, doi: 10.3390/agriengineering6030157.