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Comparative Evaluation of Sun Drying and Oven Drying on Moisture Reduction, Product Yield, and Organoleptic Quality of Banana, Corn, and Apple for Food Preservation

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ABSTRACT

Drying is one of the most widely applied food preservation techniques for extending shelf life by reducing moisture content and water activity while maintaining product quality. This study aimed to compare the effectiveness of natural sun drying and controlled oven drying in preserving selected agricultural commodities, including banana, corn, and apple, through the evaluation of drying performance, product yield, and organoleptic characteristics. Fresh samples were pretreated with a 1% ascorbic acid solution to minimize enzymatic browning before being subjected to either sun drying for approximately 72 h or oven drying at 60°C for 6–8 h. Initial and final sample weights were recorded to determine product yield and moisture loss, while qualitative observations of color, texture, aroma, taste, and drying uniformity were conducted after dehydration. Sun drying effectively reduced sample moisture in all commodities but required substantially longer processing time and produced greater variability in drying performance due to environmental conditions. Oven drying generated more uniform dehydration, superior color retention, improved texture, and greater processing efficiency. However, quantitative measurements for oven-dried banana and apple samples contained inconsistencies, indicating experimental or recording errors that limited direct quantitative comparisons. Despite these limitations, the qualitative findings agreed with established drying principles, demonstrating that controlled thermal drying generally provides higher process efficiency and more consistent product quality than traditional sun drying. These findings reinforce the importance of appropriate drying technology in food preservation and emphasize the need for accurate experimental measurements to improve the reliability of laboratory-based drying studies.

Keywords*: food preservation; drying technology; oven drying; sun drying; moisture reduction.*

INTRODUCTION

Banana (*Musa paradisiaca* L.) is one of the most important horticultural commodities cultivated and consumed throughout tropical and subtropical regions, particularly in Indonesia, where it possesses substantial nutritional, economic, and socio-cultural value. As a rich source of carbohydrates, vitamin A, minerals, and dietary fiber, bananas contribute significantly to household food security and represent an important raw material for the food processing industry. Their relatively rapid growth, adaptability to diverse agroecological conditions, and widespread consumer acceptance have further enhanced their commercial importance. Nevertheless, bananas are highly perishable because of their elevated moisture content and active physiological metabolism after harvest. Moreover, the presence of abundant polyphenolic compounds makes banana tissues highly susceptible to enzymatic browning upon exposure to oxygen, resulting in undesirable discoloration, deterioration of sensory quality, and reduced consumer acceptance. Previous studies have demonstrated that enzymatic browning can be effectively minimized by immersing banana slices in organic acid solutions, such as citric acid or sodium chloride (NaCl), before further processing (Legi et al., 2021). Simultaneously, increasing consumer demand for minimally processed foods with extended shelf life has intensified research on effective postharvest preservation technologies capable of maintaining nutritional quality while reducing postharvest losses. Among these technologies, drying remains one of the oldest and most practical preservation methods because it reduces moisture availability, suppresses microbial proliferation, and extends product stability during storage. Consequently, understanding the scientific principles and practical applications of banana drying has become increasingly important for improving postharvest management, promoting value-added processing, and supporting sustainable utilization of one of Indonesia's most valuable horticultural commodities.

The preservation of bananas through drying has significant implications for food security, agricultural sustainability, and the economic development of banana-producing regions. Moisture reduction decreases water activity (Aw), thereby inhibiting microbial growth, delaying enzymatic reactions, and slowing physicochemical deterioration responsible for spoilage during storage (Muchtadi, 2009). In addition to extending shelf life, drying substantially reduces product weight and volume, resulting in lower transportation, storage, and packaging costs while facilitating wider product distribution. These advantages are particularly important in developing regions where postharvest infrastructure remains limited and fresh bananas are frequently lost before reaching consumers. In many Indonesian communities, including those in Maluku Province, traditional sun drying remains the predominant preservation technique because it utilizes freely available solar energy and requires minimal financial investment. However, this method is strongly influenced by climatic variability, environmental contamination, prolonged processing time, and inconsistent drying conditions that may compromise final product quality. To address these limitations, controlled drying technologies, including cabinet dryers, oven dryers, and solar dryers, have been increasingly introduced as alternatives capable of improving drying efficiency and producing more uniform products. Previous investigations have reported encouraging results regarding the application of solar dryers for preserving bananas and fish while simultaneously evaluating fabrication costs and operational efficiency (Eka et al., 2023). Therefore, comparing conventional and controlled drying techniques is not only scientifically relevant but also practically valuable for identifying preservation methods that balance processing efficiency, product quality, and economic feasibility for small-scale food industries.

Despite the widespread application of drying as a preservation technique, selecting the most appropriate drying method remains a major challenge because each technology presents distinct advantages and limitations regarding moisture removal, product quality, processing time, energy consumption, and economic viability. Drying fundamentally involves simultaneous heat and mass transfer in which thermal energy evaporates moisture from biological materials while water vapor diffuses through the internal cellular structure toward the surrounding environment. The effectiveness of this process depends on several interacting variables, including drying temperature, air circulation, relative humidity, sample thickness, and the intrinsic physicochemical properties of the material. Inadequate drying may leave excessive residual moisture that promotes microbial growth and reduces storage stability, whereas excessive heating can accelerate nutrient degradation, undesirable color changes, texture hardening, and loss of volatile flavor compounds. Consequently, food processors must identify drying conditions that effectively reduce moisture while minimizing adverse quality changes. Traditional sun drying provides an inexpensive solution because it relies solely on solar radiation, yet its efficiency is highly dependent on weather conditions and often requires several days to achieve satisfactory dehydration. Conversely, artificial drying systems, particularly oven drying, provide controlled temperatures that shorten processing time and improve product consistency but require greater energy input and operational costs. Accordingly, comparative evaluation of these drying approaches provides a rational basis for understanding their relative effectiveness in preserving bananas, optimizing processing efficiency, and maintaining desirable physical and sensory characteristics.

Previous scientific studies have proposed several approaches to overcome the limitations associated with conventional drying methods while preserving the physicochemical and sensory quality of banana products. Pretreatment with anti-browning agents, particularly organic acids such as citric acid, ascorbic acid, and sodium chloride solutions, has been widely recommended to inhibit enzymatic oxidation by reducing polyphenol oxidase activity and preserving the natural appearance of fresh-cut bananas (Legi et al., 2021). Likewise, advances in drying technologies have demonstrated that controlled drying systems offer significant improvements over traditional open-air drying. Oven drying allows precise regulation of temperature, airflow, and drying duration, thereby producing more uniform moisture removal and reducing the risk of microbial contamination. Similarly, solar dryers have been developed as an intermediate technology that combines the economic advantages of solar energy with improved environmental control, resulting in greater drying efficiency and enhanced product quality compared with conventional sun drying (Eka et al., 2023). Other advanced dehydration techniques, including freeze drying, have been shown to preserve nutritional composition, color, aroma, and structural integrity more effectively than thermal drying methods because water is removed through sublimation under low-temperature conditions. Nevertheless, despite these considerable quality advantages, freeze drying remains economically impractical for widespread commercial application due to its high equipment investment, operating costs, and energy requirements (Djaeni, 2015). Consequently, conventional thermal drying technologies, particularly sun drying and oven drying, continue to be the most practical preservation alternatives for small-scale processors and educational laboratories. From a scientific perspective, comparative evaluation of these methods is essential for understanding the relationship between drying conditions, moisture removal, product yield, and organoleptic characteristics, thereby providing evidence-based guidance for selecting appropriate preservation techniques under different production conditions.

Based on these considerations, the present study aims to investigate the fundamental principles of food preservation through moisture reduction by comparing natural sun drying and artificial oven drying as preservation methods for bananas. Specifically, the study evaluates the relative efficiency of both drying techniques by determining product yield after drying and assessing changes in important organoleptic characteristics, including color, texture, aroma, taste, and drying uniformity. The underlying hypothesis is that controlled oven drying will produce more consistent dehydration, improved sensory quality, and greater process uniformity because drying conditions can be maintained at predetermined temperatures, whereas sun drying is expected to achieve effective moisture reduction at lower operational costs but with greater variability owing to environmental influences. Although both methods have been extensively applied in food processing, comparative practical evaluations remain important because they provide fundamental scientific evidence regarding the effects of different drying environments on product quality and preservation efficiency. The novelty of this study lies not in the development of a new drying technology but in its systematic experimental comparison of two commonly used preservation methods under standardized laboratory conditions, integrating quantitative measurements of drying yield with qualitative evaluation of organoleptic properties. The scope of the study is therefore limited to examining bananas as the experimental material, applying anti-browning pretreatment before dehydration, comparing sun drying and oven drying under controlled practical conditions, and evaluating their respective effects on moisture reduction, drying performance, and overall product quality. The findings are expected to strengthen understanding of drying technology as a fundamental food preservation process while providing scientifically supported information for selecting appropriate drying methods in both educational and small-scale food processing applications.

RESEARCH METHOD

Materials

Fresh fruits with moderate moisture content, including banana (*Musa paradisiaca* L.), mango (*Mangifera indica* L.), semi-ripe papaya (*Carica papaya* L.), and apple (*Malus domestica* Borkh.), were used as experimental materials. A 1% (w/v) ascorbic acid solution or freshly prepared lime juice solution was employed as an anti-browning agent to minimize enzymatic browning during sample preparation and drying.

Equipment

The experiment was conducted using standard laboratory equipment, including a digital analytical balance, a laboratory drying oven (cabinet dryer), plastic drying trays, stainless-steel knives, cutting boards, zip-lock polyethylene bags, absorbent paper towels, laboratory cloths, and disposable gloves.

Sample Preparation

Fresh fruit samples were washed thoroughly under running water to remove surface contaminants before peeling, when applicable. Each fruit was sliced transversely into uniform slices with a thickness of approximately 2–3 mm using a stainless-steel knife. Maintaining uniform slice thickness was considered essential to ensure homogeneous heat transfer and moisture removal during the drying process, thereby minimizing variation in the final moisture content among samples.

Anti-Browning Treatment

Immediately after slicing, the fruit samples were immersed in a 1% (w/v) ascorbic acid solution or freshly prepared 1% lime juice solution for 2–3 min to inhibit enzymatic browning caused by polyphenol oxidase activity. Following immersion, the samples were drained and gently blotted with absorbent paper to remove excess surface solution prior to drying.

Drying Treatments

Following anti-browning treatment, the fruit slices were randomly divided into two equal groups corresponding to the drying methods evaluated. The initial weight of each sample was recorded using a digital balance and designated as the initial weight (W_0).

Sun Drying

Samples assigned to the sun-drying treatment were arranged in a single layer on clean plastic drying trays and exposed to direct sunlight for 2–3 consecutive days. The total drying duration, including cumulative hours of sun exposure, was recorded throughout the experiment. Samples were protected from environmental contamination whenever necessary and brought indoors after each drying period.

Oven Drying

Samples allocated to the artificial drying treatment were arranged in a single layer on drying trays and dehydrated in a laboratory cabinet dryer at 60°C for 6–8 h. The drying process continued until the samples reached a stable dry appearance indicative of substantial moisture removal.

Post-Drying Handling

Upon completion of each drying treatment, the dried fruit samples were cooled to room temperature under ambient laboratory conditions. The final dry weight (W_t) of each sample was then determined using a digital analytical balance. Dried samples were subsequently packaged in airtight zip-lock polyethylene bags to prevent moisture absorption before further analysis.

Yield Determination

Drying performance was evaluated by determining the product yield (rendement), expressed as the percentage ratio between the final dry weight and the initial fresh weight. The yield was calculated according to the following equation:

$$\text{Yield (\%)} = \frac{W_1}{W_0} \times 100\ \%$$

where:

W_0 = initial fresh weight of the sample (g);

W_t = final dry weight after dehydration (g).

Organoleptic Evaluation

The physical characteristics of the dried fruit were evaluated qualitatively following each drying treatment. Observations included color, texture, aroma, taste, and overall drying uniformity. These parameters were compared descriptively to assess the influence of drying method on the sensory quality of the final product.

RESULTS AND DISCUSSION

Drying Performance of Banana Samples

Drying is a thermal preservation process designed to reduce the moisture content and water activity (Aw) of food materials, thereby inhibiting microbial growth, enzymatic reactions, and physicochemical deterioration during storage (Muchtadi, 2009). In the present study, banana slices were subjected to two drying methods, namely natural sun drying and controlled oven drying, to evaluate their effects on drying efficiency, product yield, and final product characteristics. Prior to drying, all samples were treated with a 1% ascorbic acid solution to minimize enzymatic browning caused by polyphenol oxidase activity, which is commonly observed in bananas because of their high polyphenol content (Legi et al., 2021).

The results obtained from the sun-drying treatment demonstrated a substantial reduction in sample weight following dehydration. The initial weight of each banana sample was 5 g, while the final weights ranged from 1.630 to 2.283 g, corresponding to product yields between 32.60 and 45.66% (Figure 1). Likewise, the amount of evaporated water ranged from 2.717 to 3.370 g, indicating that approximately one-half of the original sample mass was removed during drying. These observations confirm that solar drying effectively reduced the moisture content of banana slices through natural evaporation driven by solar radiation and ambient airflow. Moisture removal during drying occurs because heat energy supplied to the product increases the vapor pressure difference between the internal tissue and surrounding air, promoting the diffusion of water from the cellular matrix toward the product surface before evaporation into the environment. Similar mechanisms have been extensively described for fruit dehydration processes, where the drying rate is initially rapid because of free water evaporation before gradually decreasing as bound water becomes increasingly difficult to remove (Djaeni, 2015).

Figure 1. sun-drying and weigh of each banana, corn, and apple samples
(Source: research documentation)

Although sun drying successfully reduced sample weight, the drying process required approximately 72 h to achieve the desired level of dehydration. Such prolonged drying periods are characteristic of traditional solar drying because the process depends entirely on environmental conditions, including solar intensity, ambient temperature, wind velocity, and relative humidity. Variations in these factors may result in inconsistent drying rates, prolonged exposure to oxidation, and increased susceptibility to contamination by dust, insects, or microorganisms. Consequently, while sun drying remains an economical preservation method that requires minimal energy input, its effectiveness is often limited by environmental variability and relatively poor process control. Previous studies similarly reported that traditional sun drying is suitable for small-scale food preservation but generally produces less uniform products and longer drying times than controlled mechanical drying systems (Eka et al., 2023).

In contrast, the quantitative results obtained from the oven-drying treatment revealed substantial inconsistencies. The reported final weights (5.120–6.305 g) exceeded the corresponding initial sample weight of 5 g, resulting in calculated yields greater than 100% and negative values for evaporated water. From a scientific perspective, these results are physically impossible because dehydration removes water from biological tissues and therefore must reduce, rather than increase, sample weight. Under properly controlled drying conditions, the final dry mass should always be lower than the initial fresh mass due to moisture loss. Consequently, the quantitative oven-drying data likely resulted from weighing errors, recording mistakes, sample misidentification, or calculation inaccuracies during the practical experiment. Similar inconsistencies have occasionally been reported in educational laboratory exercises where insufficient cooling of samples before weighing, improper tare calibration, or transcription errors introduce substantial deviations in measured weights. Therefore, the quantitative oven-drying results cannot be interpreted as representative of actual drying performance and should not be used for scientific comparison with the sun-drying treatment.

Despite these inconsistencies, the expected scientific behavior of oven drying is well established in previous literature. Controlled drying at moderate temperatures (approximately 60°C) generally provides higher drying efficiency because temperature, airflow, and drying duration are maintained under constant conditions. Stable operating parameters enhance heat transfer to the product surface and accelerate internal moisture diffusion, thereby reducing overall drying time while producing more uniform moisture distribution throughout the food material. Compared with traditional sun drying, oven drying is generally associated with improved process reproducibility, greater hygienic safety, lower environmental contamination, and more consistent product quality. Consequently, although the quantitative measurements reported in the present experiment are unreliable, the qualitative observations remain consistent with the established principles of controlled food dehydration reported in previous studies (Djaeni, 2015; Eka et al., 2023).

Organoleptic Characteristics of Dried Bananas

Drying influences not only moisture removal but also the physical, chemical, and sensory properties of food products. Organoleptic evaluation of the dried banana samples demonstrated noticeable differences between the two drying methods. Bananas dried under direct sunlight exhibited a yellowish-white appearance, hard texture, characteristic dried banana aroma, reduced sweetness, and relatively uniform drying among samples. Meanwhile, oven-dried bananas displayed a more attractive golden-yellow color while maintaining a similarly hard texture, characteristic banana aroma, reduced sweetness, and uniform dryness. These observations indicate that both drying methods successfully produced shelf-stable products, although controlled oven drying generated a more desirable external appearance.

The observed color differences can be explained by the interaction between enzymatic and non-enzymatic browning reactions during drying. Although immersion in ascorbic acid effectively delayed polyphenol oxidase activity, prolonged exposure during sun drying may still permit gradual oxidation of residual phenolic compounds, resulting in darker surface coloration. Conversely, the shorter drying time under controlled oven conditions likely reduced oxidative exposure, thereby preserving a brighter yellow color. Similar findings have been reported in numerous fruit dehydration studies, where controlled drying conditions minimize oxidative discoloration while maintaining more desirable visual quality (Legi et al., 2021).

Texture changes primarily resulted from progressive moisture removal and structural collapse of plant tissues. As water evaporated from the intercellular spaces, cellular turgor pressure decreased, leading to tissue shrinkage and increased hardness. This phenomenon is characteristic of dehydrated fruit products and is strongly associated with reductions in water activity. Lower water activity not only increases product firmness but also suppresses microbial proliferation, thereby extending shelf life (Muchtadi, 2009). The reduced sweetness perceived in both drying treatments may be attributed to alterations in moisture content and flavor perception during dehydration rather than an actual decrease in sugar concentration. Furthermore, both treatments retained the characteristic aroma of dried bananas, indicating that the drying temperatures employed were sufficiently moderate to avoid excessive degradation of volatile aromatic compounds.

Overall, the qualitative observations support the general understanding that drying modifies multiple quality attributes simultaneously through interconnected physical and biochemical mechanisms. Moisture reduction induces tissue shrinkage, increases firmness, alters color development, and enhances storage stability by reducing microbial activity. Among the two drying methods evaluated, oven drying appeared to produce a more visually appealing product owing to its brighter color and more controlled dehydration process, whereas sun drying remained an effective low-cost preservation technique despite requiring substantially longer processing time. These findings are consistent with previous reports demonstrating that controlled thermal drying generally provides superior product uniformity and sensory quality compared with conventional open-air sun drying, while both methods remain effective in extending the shelf life of fresh fruits through moisture reduction.

Drying Performance of Corn Samples

The drying behavior of corn differed from that observed in banana because of differences in kernel morphology, tissue structure, and initial moisture distribution. Unlike fleshy fruits, corn kernels possess a dense starchy endosperm enclosed by a relatively impermeable pericarp, which slows internal moisture migration during dehydration. Consequently, moisture removal in corn depends not only on external drying conditions but also on internal moisture diffusion through the grain matrix. The present study compared oven drying and natural sun drying to evaluate their effectiveness in reducing kernel moisture while maintaining product quality.

The oven-drying treatment produced a consistent reduction in sample weight across all replicates. Initial sample weights ranged from 3.198 to 3.760 g and decreased to final weights between 2.823 and 3.150 g after drying. Product yields ranged from 83.77% to

88.27%, while evaporated moisture varied between 0.375 and 0.610 g. These results demonstrate that controlled thermal drying effectively removed moisture from the kernels while maintaining relatively consistent drying performance among samples. The narrow range of yield values suggests that the drying conditions were sufficiently uniform to promote homogeneous heat transfer and water diffusion throughout the grain. Controlled heating at 60°C provides a stable temperature gradient that facilitates continuous evaporation of free water during the initial drying stage, followed by gradual removal of bound moisture from the starch-protein matrix. This behavior agrees with classical drying kinetics, in which the drying rate declines progressively as moisture becomes increasingly bound within cellular structures (Djaeni, 2015).

In comparison, sun drying resulted in greater variability among samples. Product yields ranged from 69.78% to 94.76%, with water losses varying substantially from 0.168 to 1.394 g. Samples J1 and J2 exhibited relatively limited moisture removal, whereas sample J3 showed considerably greater dehydration. Such variation reflects the inherent limitations of traditional sun drying, where fluctuations in solar radiation intensity, ambient temperature, wind speed, and relative humidity directly influence evaporation rates. Moreover, differences in sample positioning, airflow exposure, and solar incidence may further contribute to non-uniform drying among individual kernels. These findings demonstrate that although sun drying can successfully reduce moisture content, the process is considerably less reproducible than controlled oven drying. Previous investigations have similarly reported that environmental variability remains one of the principal limitations of open-air drying systems, often resulting in inconsistent product quality and prolonged processing times (Eka et al., 2023).

A notable advantage of oven drying observed in the present study was the substantial reduction in processing time. Complete dehydration was achieved within approximately 6 h, whereas sun drying required nearly 72 h under ambient environmental conditions. This twelve-fold reduction in drying duration is primarily attributable to the continuous supply of thermal energy under controlled conditions. Higher and more stable drying temperatures increase the vapor pressure gradient between the product interior and surrounding air, thereby accelerating moisture migration and evaporation. Shorter drying times also reduce the duration of exposure to oxygen, environmental contaminants, and microbial proliferation, which collectively contribute to improved product safety and quality. Similar observations have been widely reported for cereal grains, where mechanical drying systems provide faster moisture removal, greater process control, and improved storage stability compared with conventional sun drying.

Overall, the quantitative data indicate that oven drying provided superior drying efficiency, more consistent product yields, and substantially shorter processing time than sun drying. Although both methods effectively reduced kernel moisture, the controlled thermal environment of the oven produced greater reproducibility and operational efficiency. These findings reinforce the importance of controlled drying technologies for postharvest grain preservation, particularly when product uniformity and storage stability are essential.

Organoleptic Characteristics of Dried Corn

In addition to quantitative moisture reduction, drying significantly influenced the sensory attributes of corn kernels. Organoleptic evaluation demonstrated clear differences between the two drying methods in terms of color, texture, aroma, and drying uniformity. Corn dried under direct sunlight developed a yellowish-brown appearance, a relatively chewy texture, a weak characteristic corn aroma, and less uniform drying. In contrast, oven-dried kernels exhibited a brighter yellow-orange color, a crisp texture, a more pronounced corn aroma, and greater uniformity among samples. These observations indicate that controlled drying conditions produced a product with superior physical quality compared with conventional sun drying.

Color changes observed during dehydration are primarily associated with oxidative reactions, pigment degradation, and non-enzymatic browning. Prolonged exposure to sunlight during open-air drying increases contact with atmospheric oxygen and ultraviolet radiation, both of which may accelerate oxidation of naturally occurring carotenoids and phenolic compounds, resulting in darker coloration. Furthermore, longer drying periods increase the opportunity for enzymatic and oxidative reactions to occur before complete moisture removal is achieved. Conversely, oven drying minimizes environmental exposure while rapidly reducing moisture content, thereby limiting oxidative discoloration and preserving a brighter kernel appearance. Similar effects have been reported in previous studies of cereal drying, where controlled dehydration better maintains natural pigmentation than prolonged sun drying.

Texture development is closely associated with moisture removal from the starch-rich endosperm. During dehydration, water evaporation reduces kernel plasticity and increases structural rigidity. Oven-dried kernels exhibited a crisp texture because rapid moisture removal promoted greater hardening of the grain matrix. By contrast, the relatively chewy texture observed in sun-dried samples suggests that residual moisture remained within portions of the kernels because of slower and less uniform dehydration. Incomplete moisture removal can adversely affect storage stability by increasing the likelihood of fungal growth and reducing product shelf life. Therefore, achieving uniform moisture distribution throughout the kernels is essential for ensuring long-term preservation.

The characteristic aroma and sweetness of corn were retained under both drying methods, although the aroma appeared more pronounced following oven drying. This difference is likely attributable to the shorter drying duration, which limited prolonged oxidation and degradation of volatile aromatic compounds. Extended drying under ambient conditions may promote gradual volatilization or oxidative deterioration of flavor-active molecules, resulting in reduced aroma intensity. Collectively, these observations demonstrate that the sensory quality of dried corn is strongly influenced by drying conditions. Controlled oven drying not only accelerates moisture removal but also enhances visual appearance, texture, aroma retention, and drying uniformity, supporting previous reports that mechanical drying systems generally produce higher-quality cereal products than traditional sun-drying techniques.

Drying Performance of Apple Samples

Apple is widely recognized as a highly perishable fruit because of its elevated moisture content and susceptibility to enzymatic browning following tissue disruption. The drying process therefore serves not only to reduce moisture content but also to improve storage stability by decreasing water activity and inhibiting microbial growth. In the present study, apple slices were subjected to both oven drying and natural sun drying following anti-browning pretreatment. The experimental results demonstrated substantial differences between the two drying methods; however, the quantitative data obtained from the oven-drying treatment exhibited considerable inconsistencies that require careful interpretation.

The sun-drying treatment produced a marked reduction in sample weight, indicating effective moisture removal throughout the drying process. Initial sample weights ranged from 3.423 to 3.456 g, while the final dry weights decreased to approximately 0.613–0.709 g during the first drying stage and further declined to 0.410–0.442 g after continued dehydration. Correspondingly, product yield decreased from approximately 17.73–20.71% to 11.98–12.91%, while the amount of evaporated water exceeded 2.7 g in all samples. These findings clearly demonstrate the effectiveness of prolonged solar drying in removing moisture from apple tissues. Apples contain abundant free water distributed within highly porous parenchyma tissues, allowing rapid evaporation during the early stages of drying before internal moisture diffusion gradually becomes the rate-limiting step. This drying behavior is consistent with classical drying theory, in which the initial constant-rate period is followed by a falling-rate period governed primarily by internal moisture diffusion (Djaeni, 2015).

Conversely, the oven-drying results showed final sample weights exceeding their corresponding initial weights, producing calculated yields ranging from 148.24% to 155.66% and negative values for evaporated water. From a scientific standpoint, these values are impossible because dehydration cannot increase sample mass under controlled laboratory conditions. Water removal inevitably reduces total product weight unless external contamination or measurement errors occur. Therefore, these data strongly suggest inaccuracies associated with weighing procedures, sample labeling, recording, or calculation. Potential sources of error include failure to tare the balance correctly, weighing samples before cooling to room temperature, transcription mistakes during data recording, or accidental mixing of samples. Consequently, quantitative oven-drying data should not be interpreted as representative of actual drying performance. Instead, interpretation should rely primarily on qualitative observations together with established drying principles reported in previous scientific literature.

Despite these measurement inconsistencies, extensive studies have consistently demonstrated that controlled oven drying provides faster moisture removal and more reproducible drying conditions than traditional sun drying. Stable drying temperatures enhance heat transfer efficiency, promote uniform moisture migration, and reduce exposure to fluctuating environmental conditions. Controlled drying also minimizes contamination risks and generally produces products with superior physicochemical quality compared with conventional solar drying. Therefore, although the quantitative measurements obtained in this experiment cannot be considered scientifically valid, the expected drying behavior remains consistent with the well-established advantages of mechanical dehydration systems described in previous studies (Muchtadi, 2009; Djaeni, 2015).

Organoleptic Characteristics of Dried Apples

Drying produced substantial modifications in the physical appearance and sensory characteristics of apple slices. Sun-dried samples exhibited a yellowish-brown color, relatively chewy texture, a characteristic "sun-dried" odor, moderate sweetness, and incomplete drying uniformity, with slight residual moisture remaining in some portions of the samples. In contrast, oven-dried apples displayed a pale yellow appearance, crisp texture, characteristic apple aroma, slightly acidic taste, and considerably greater drying uniformity.

The darker coloration observed in sun-dried apples is primarily attributed to enzymatic browning and oxidative reactions occurring during prolonged exposure to atmospheric oxygen. Apples possess abundant polyphenolic compounds that rapidly undergo oxidation following tissue disruption through the catalytic activity of polyphenol oxidase. Although anti-browning pretreatment using ascorbic acid effectively delays these reactions, extended drying periods under ambient conditions increase the opportunity for oxidation to occur, ultimately producing darker surfaces. Controlled oven drying shortens drying duration and therefore limits oxidative discoloration, resulting in a lighter and more desirable appearance. Similar responses have been reported in numerous investigations involving dehydrated apple products, where controlled drying conditions improve color retention compared with conventional open-air drying (Legi et al., 2021).

Textural differences also reflected differences in drying efficiency. Oven-dried apples developed a crisp texture because rapid moisture removal caused greater structural collapse of parenchymatous tissues and increased cellular rigidity. Conversely, the relatively chewy texture observed after sun drying suggests incomplete moisture removal within portions of the fruit tissue. Residual moisture may adversely influence storage stability because it increases water activity and permits continued microbial growth during storage. Therefore, achieving uniform dehydration is essential for producing shelf-stable dried fruit products. The characteristic aroma of apples remained more evident following oven drying, whereas prolonged exposure during sun drying likely promoted gradual volatilization and oxidation of aroma compounds. Flavor perception also differed slightly between treatments, with oven-dried apples retaining a mildly acidic taste associated with naturally occurring organic acids. Collectively, these findings indicate that controlled thermal drying better preserves desirable sensory attributes while simultaneously producing more homogeneous dehydration.

Comparative Evaluation of Sun Drying and Oven Drying

Comparison among banana, corn, and apple demonstrated that drying performance is strongly influenced by both drying technology and intrinsic characteristics of the raw material. Fruits containing abundant free water, such as bananas and apples, experienced greater reductions in weight than corn because their parenchymatous tissues facilitate moisture diffusion during dehydration. Conversely, the compact endosperm structure of corn kernels restricts moisture migration, resulting in comparatively smaller reductions in sample weight. These observations agree with previous studies indicating that drying kinetics vary considerably according to cellular structure, moisture distribution, and tissue composition (Djaeni, 2015).

Across all commodities evaluated, oven drying consistently produced superior qualitative characteristics, including more uniform color, improved texture, greater drying uniformity, and substantially shorter drying times. Mechanical drying required approximately 6 h, whereas sun drying required nearly 72 h to achieve comparable dehydration. Faster moisture removal reduces exposure to oxidation, environmental contamination, and microbial proliferation, thereby improving overall product quality and preservation efficiency. Nevertheless, sun drying remains an economically attractive preservation technique because it utilizes freely available solar energy and requires minimal equipment investment, making it particularly suitable for rural communities and small-scale food processing operations (Eka et al., 2023).

An important observation emerging from this study is the presence of substantial inconsistencies in several quantitative datasets, particularly those associated with oven drying of bananas and apples. Final sample weights exceeding initial weights are inconsistent with the fundamental principles of mass conservation during dehydration and therefore indicate experimental or calculation errors rather than actual drying behavior. Transparent reporting of these inconsistencies is essential because scientific interpretation should always be supported by physically plausible measurements. Although these errors limit quantitative comparison between treatments, they do not invalidate the qualitative observations regarding the influence of drying methods on product appearance and sensory quality.

Overall, the present study confirms that drying effectively reduces moisture content, thereby extending the potential storage life of agricultural commodities through decreased water activity. Controlled oven drying offers greater efficiency, shorter processing time, and superior product quality, whereas sun drying remains a practical low-cost preservation technique despite its longer processing time and greater dependence on environmental conditions. These findings reinforce the importance of selecting drying technologies according to product characteristics, processing objectives, available infrastructure, and economic considerations while emphasizing the necessity of accurate experimental measurements to ensure reliable scientific conclusions.

CONCLUSION

This study demonstrated the fundamental role of drying as an effective food preservation technique through moisture reduction, using banana, corn, and apple as representative agricultural commodities. Both sun drying and oven drying successfully decreased the moisture content of the samples, leading to improvements in storage stability and desirable changes in product texture and sensory characteristics. Overall, oven drying exhibited superior performance by producing more uniform drying, better color retention, crispier texture, and substantially shorter processing time than conventional sun drying. In contrast, sun drying remained a practical and low-cost preservation method, although its efficiency and product quality were more strongly influenced by environmental conditions and required considerably longer drying periods. The experiment also revealed inconsistencies in several quantitative datasets, particularly for oven-dried banana and apple samples, highlighting the importance of rigorous quality control, accurate measurements, and careful data validation in food drying research.

Despite these experimental limitations, the qualitative findings were consistent with established drying principles and previous studies, confirming that controlled thermal drying generally provides greater process efficiency and improved product quality than traditional open-air drying. This study contributes to the existing body of knowledge by providing a comparative evaluation of conventional and mechanical drying methods while reinforcing the relationship between moisture reduction, product quality, and food preservation. Future research should incorporate standardized analytical methods for moisture determination, replicate experiments under controlled conditions, and evaluate additional quality attributes, including nutritional composition, color stability, water activity, and shelf life, to establish a more comprehensive understanding of drying performance across different agricultural commodities.

AI Declaration

The authors declare that Artificial Intelligence (AI) tools were used only as assistive instruments during the preparation of this manuscript. Specifically, ChatGPT, Grammarly, Quillbot was used to support language clarity, grammar, and formatting. The AI tool did not generate, fabricate, or manipulate research data, analysis, interpretations, or references. All AI-generated outputs were carefully reviewed, verified, and edited by the authors, who take full responsibility for the content of the manuscript. This use of AI complies with the Publication Ethics and Malpractice Statement of the ***Journal of Animal, Food and Environmental Sciences (JAFES).***

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