Paper ID 37: Changes in Some Nutritional Values of Mango (*Mangifera Indica*) During Drying

A. L. Adepoju[1*], Z. D. Osunde[2], O.V. Adeyinka-Ajiboye[3]
[1]Department of Food Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Nigeria
[2]Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria
[3]Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Nigeria

*Corresponding author: adepoju.al@unilorin.edu.ng

ABSTRACT

Mangoes (*Mangifera indica*), like many fresh fruits, contain more than 80% water, a characteristic that makes them highly perishable with a naturally short shelf life. High moisture content, combined with exposure to ambient temperature and microbial activity, accelerates deterioration, resulting in significant post-harvest losses if preservation measures are not employed. Among the various preservation techniques available, drying stands out as one of the most suitable and cost-effective methods for extending the shelf life of mangoes. By removing water to safe levels, drying effectively suppresses microbial growth and enzymatic activity, thereby maintaining the fruit's safety and quality during storage and distribution. However, the drying process can induce notable changes in nutritional composition. Moisture content decreases significantly, and heat-sensitive vitamins such as vitamin C may be partially lost. At the same time, the removal of water leads to the concentration of sugars, dietary fibre, and phytochemicals such as antioxidants. The extent of these changes is influenced by the drying method employed, the duration of the process, and the use of pretreatments. Despite some nutrient losses, dried mango generally retains substantial amounts of nutrients such as vitamins and minerals. This makes dried mango a healthy snack and a versatile ingredient in the food industry.

keywords: Mango, Nutritional values, Pretreatment, Drying, Dried fruits.

1. Introduction

Mango (Figure 1) is a fleshy stone fruit belonging to the *Anacardiaceae* family with a delicious taste and delightful aroma. Though mango is native to Asia, it has been distributed worldwide to become one of the most cultivated fruits in many tropical and sub-tropical countries. Though over 1000 Mangifera species are grown all over the world, *Mangifera indica* (also known as the Indian mango) is the most cultivated species in many regions (Adepoju and Osunde, 2017; Lebaka *et al.*, 2021; Tran *et al.*, 2023). According to a Food and Agriculture Organization report, mango was ranked as the predominant tropical fruit in the 21st century, with global mango production of over 28 million tons in 2014 (which accounts for 35% of global tropical fruit production) and 51 million tons in 2019 (Zikri *et al.*, 2022).



Figure 1: Mango tree with fruits

Mango fruit has proved to be essential for a balanced diet and a healthy life. It is considered a fruit with high commercial value due to its nutrient composition. Fresh mangoes are a rich source of nutrients such as carbohydrates, and dietary fiber, vitamins, including vitamin C, vitamin A, and vitamin B6; several macro and microelements minerals, including potassium, magnesium, and calcium and antioxidants such as polyphenols and carotenoids are reportedly present in mango (Hussain *et al.*, 2024). It also contains various phytochemicals such as phenolic and polyphenolic compounds, gallic acid, benzophenones, flavonoids, and carotenoids (Sayago-Ayerdi *et al.*, 2021; Sulistyawati *et al.*, 2020). Some proximate contents of a typical mango fruit are presented in Table 1 as stated by Yahia *et al.* (2023). These nutrients make the regular intake of mangoes, like other fruits, of great health benefits to consumers. They are good sources of natural sugars such as sucrose, glucose, and fructose; they help maintain a healthy digestive system and protect the body from oxidative stress and chronic diseases (Mongi and Ngoma, 2022).

Table 1: Major (proximate) components of mango fruit

Parameter	Content (g/100g DW)
Water	78-83
Ash	0.34-0.52
Lipids	0.30-0.53
Proteins	0.36-0.40
Carbohydrates	16.20-17.18
Dietary fibers	0.85–1.06
Energy (kcal)	62.1–190

Source: (Yahia *et al.*, 2023)

Mangoes are classified as highly perishable and bulky commodities because they contain more than 80% moisture and are therefore prone to deterioration (Caparino *et al.*, 2012). The bulkiness and perishable nature make its transportation to distant places somewhat costly, and its condition on arrival in those places may be less than satisfactory. The best way to maintain these fruits' nutritional value is by keeping the products fresh. However, most of the storage methods require very low temperatures, which are difficult to maintain throughout the chain, mainly in developing countries. These difficulties with the short storage life of mango fruits are often worsened by the poor transport and marketing system in developing countries, leading to a huge post-harvest loss (Ampah *et al.*, 2022). These losses are mainly due to the perishable nature of mango, poor postharvest handling and marketing conditions, and lack of cheap and appropriate postharvest technology. Mango fruits produced in the peak periods, especially in developing countries, are either consumed fresh, sold at relatively inexpensive prices, or allowed to go to waste due to inadequate processing and storage facilities (Dereje and Abera, 2020). Drying of the fruits reduced these losses.

2. Drying of Mango

Drying is generally regarded as one of the oldest methods for the preservation of food products, including fruits such as mango (Manzoor *et al.*, 2019; Omolola *et al.*, 2015). It is the process of removing water from food by circulating hot air through it to reduce the moisture content to a level that prohibits the growth of microorganisms. It also helps to combat the problem of perishability and seasonality of mangoes by prolonging their shelf life and increasing their diversity (Mohammed *et al.*, 2020). Drying of food materials has advantages such as the extension of shelf life, control of product quality, achievement of hygienic conditions, and elimination of the use of expensive refrigeration systems for transport and storage; reduction of space required for storage and transport, reduction of product loss and offering availability of variety supply of foods with different functionality, thus offering the consumers a great choice of selection when buying foods (Guiné, 2018; Suherman *et al.*, 2023). By reducing the moisture content of mango fruit through drying, bacteria, yeast, mold, and enzymes can be prevented from spoiling it, and the flavor and most of the

nutritional value can be preserved and concentrated(Deng *et al.*, 2017). Mango drying removes water in different forms (free and bound) to preserve the fruit from spoilage and increase its shelf life. It has a long tradition of facilitating the preservation of fruits, especially mango.

Mango may be dried in many ways, such as in sliced/chip form (Castillo Téllez *et al.*, 2022a; Melesse and Emire, 2022; Suherman *et al.*, 2023; Techane, 2022); as leather (Teshome, 2010), or as puree/juice into powder form (Caparino *et al.*, 2012; Kongpichitchoke *et al.*, 2021; Tran *et al.*, 2023). The residual or final moisture content of dried mango varies from small (3–8%) to large (16–18%) amounts, depending on the desired usage of the end product (FAO, 2020). While drying, attention must be given to certain characteristics of mango fruit, such as very high initial moisture content, high sensitivity to temperature (color, flavor, texture, and nutritional value), high susceptibility to microbial attack, and high sugar content (which gives rise to problems of stickiness and fermentation). These characteristics will help in selecting the appropriate type of dryer as well as the operating conditions of drying, which in turn, help to enhance the quality of the dried mango. When properly planned, drying of mango can be accomplished with little capital while maintaining high quality and obtaining less perishable food products.

3. Drying Methods for Mango

Different types of dryers and drying methods, each better suited for a particular situation, are commercially used to remove moisture from a wide variety of fruits, including mango. In selecting a suitable method for drying mango at a particular instant, a lot of factors come into play, such as the number of mangoes, available resources, time, desired end product, necessary operating conditions, and operation costs (Verma *et al.*, 2020). Some of the basic types of drying methods that may be used in the drying of mango are briefly discussed in Table 2. Dried mango, like every other fruit, contains concentrated fruit sugars, which make it a good source of energy. It is high in fiber and carbohydrates and low in fat, making it a healthy food choice, especially for people with health challenges (Ampah *et al.*, 2022). Dried mango is rich in vitamins and minerals like calcium and phosphorus, which are extremely important for healthy bones and teeth. Dried mangoes could be consumed directly or used as secondary raw materials for other products. Dried mangoes are used at home (as a snack or cooking ingredient), out of the home (in hotels, restaurants, and other places), and in the food industry (in bakery and confectionery products or breakfast cereal mixtures). Dried mangoes for snacking are usually sold in plastic bags or pouches, and they are eaten as a healthy substitute for sweets, chocolate, or crisps. Dried mango used as an ingredient in the food-processing industry is usually in the form of slices, chunks, diced pieces, or granules. It can also be used as a sugar substitute and as a healthy seasoning (CBIMI, 2021). Dried fruit, including mango, is also used to prevent constipation because they are rich in fiber, aids digestion, and helps maintain a healthy colon. Dried mango possesses powerful antioxidants that help in preventing free radical damage in the body; thereby enabling it to fight away various health issues, such as varicose veins, hemorrhoids, glaucoma, peptic ulcers, cataracts, heart disease, as well as cancer (Omolola *et al.*, 2015). Dried mango also helps to increase the functionality of the fruit and food security (Chibuzo *et al.*, 2021). Dried mango is easy to carry around, which is why sportspeople, hikers, and other athletes love to carry it with them. It can also be made into health bars, which are a tasty snack in themselves. Dried mango (Figure 2) can be consumed directly, sprinkled on top of cereal, or whipped up with some chilled yogurt. It can also be frozen to conserve the important nutrients contained in it.



Figure 2: Dried mango slices

Table 2: Some Basic Drying Methods commonly used in mango drying

Drying Methods	Merits	Demerits	References
Sun drying	Sun drying is an inexpensive method to use for drying mangoes, especially in developing countries. Sun drying is suitable for mango drying in tropical areas with at least 6 hours of sunlight and as much as 500-800 W/m² radiation per hour.	This method is quite slow because it is dependent on weather changes, and this often results in products of lower quality. While drying mango with the sun, different lots at various stages of maturity (ripeness) cannot be mixed.	(Citra *et al.*, 2021)
Solar drying	Solar drying methods are environmentally friendly and economically viable in developing countries. This method is cost-effective, and the dryers can be locally constructed and do not require any power from the electrical grid or fossil fuels. These make solar drying applicable for household drying. Forced convection solar dryers have a higher drying rate and capacity in comparison to natural convection ones, which makes them suitable for commercial drying of fruits, including mango.	Solar drying possesses the disadvantages of extremely low buoyancy-induced airflow inside the dryer, limited capacity, and the risk of crop spoilage during adverse conditions.	(Castillo Téllez *et al.*, 2022; Ekpo *et al.*, 2022; Verma *et al.*, 2020)
Mechanical (cabinet) drying	In the mechanical drying method, important drying parameters such as temperature, humidity, and airflow can be controlled. This method has the advantages of faster drying rates, less floor space, and uniformity of drying. It is also hygienic, not weather dependent, and possesses a higher yield of quality dried product, coupled with better rehydration properties in comparison with sun and solar drying. This method is flexible as it can be used for drying mangoes on a bench-scale unit holding one or two small trays of fruit or on a commercial scale.	This drying method is expensive and may be difficult to acquire for small-scale farmers and food processors. It requires the use of heaters, which further increases the cost of energy consumption.	(Chibuzo *et al.*, 2021)
Fluidized bed drying	The operation involved in the fluidized bed drying method gives rise to important advantages such as good solids mixing, high rates of heat and mass transfer leading to a high rate of moisture removal, easy material transport, high thermal efficiency, and low maintenance cost.	With the use of fluidized bed drying, there can be poor fluidization quality of particulate products. High operating cost due to high electrical power consumption. There may be a problem of non-uniformity of product quality in some cases.	(Mujumdar, 2006)

Spray drying	This method of drying can produce exceptionally high-quality dried products, and if the particles are removed quickly from the drying chamber once they are dried, heat damage is limited. Spray drying can also be used to dry relatively heat-sensitive materials (mango fruit included). This method can also help to convert mango juice, puree, or pulp into powder. This, in turn, will cause a reduction in transportation and handling costs. The spray drying method gives rise to dried food powder with increased versatility and functionality in the food industry. The spray drying method is a continuous process and can be easily installed. It has high performance due to low residence time (of a few seconds); its single-step powder production can help maximize profit and simplify the process.	Efficient spray-drying plant design requires considerable expertise along with access to large-scale test facilities, particularly where particle size and bulk density requirements in the dried product are critical. This method of drying is also expensive to set up and may not be affordable for small-scale food processors.	(Citra *et al.*, 2021; Verma and Singh, 2015)
Drum drying	This method is suitable for mangoes that are in liquid, puree, and paste-like forms. Depending on the food material, freeze-drying can be achieved in one minute or less, especially when the fruit/food to be dried is less than 2mm thick.	Drum-dried food generally has a more cooked flavour when compared with its spray-dried counterparts due to the high temperature the food is exposed to towards the end of drying.	(Prangpru *et al.*, 2017)
Freeze drying	The freeze-drying method is usually done at a low temperature, lower than in most other methods of drying, so heat damage is relatively low. Due to its low drying temperature, there is little or no loss in sensory qualities of the product dried by freeze-drying. Fruits dried by freeze drying method tend to rehydrate rapidly because the removal of ice crystals during the drying process leaves a porous honeycomb structure. Mango puree that is freeze-dried yields powders of excellent quality for taste, flavour, and reconstitution properties.	The freeze-drying method is slow with a long processing time. Additional energy is required to run the compressor and refrigeration unit, and this makes the process very expensive for commercial use. It is most often used for products that can either be sold at a premium price or that can withstand only a small amount of sensory deterioration.	(Suherman *et al.*, 2023)
Osmotic dehydration	This method gives rise to better nutrient retention when used for drying mangoes, as the high concentration of the solute surrounding the fruits prevents discoloration of the product. It also reduces heat damage to colour and flavour because dehydration is done at ambient temperature.	Dried mango that is produced through this method is not usually stable, and further processing, such as hot air drying or freezing, may be necessary to stabilize the dried fruit. Osmotic dehydration cannot be used solely for drying, but as a pretreatment before mango drying.	(Radojčin *et al.*, 2021)

The table is based on the findings of this study.

4. Major Changes in Nutritional Values of Mango During Drying

Drying is a method of preserving mangoes that involves removing the moisture from the fruit. Though some of the nutritional values of mangoes may be altered during the drying process, dried mangoes are still a nutritious and healthy snack option. However, they may have higher calorie and sugar content than fresh mangoes, so they should be consumed in moderation. The major changes that occur in the nutritional values of mango during drying include the reduction in water content, which is the most significant change during drying. Fresh mangoes contain around 80-85% water, while dried mangoes contain only 12–14% water, just like other dried agro-products (Vera Zambrano *et al.*, 2019). As a result, the nutrient concentrations in dried mangoes are more concentrated than in fresh mangoes. The calories in dried mangoes increase and this is because the water content is removed during drying, leaving behind a more concentrated source of calories. Dried mango also has increased fiber, sugar, and antioxidant contents, while vitamin C, a water-soluble vitamin, is lost during the drying process.

5. Pretreating Mango Fruits Before Drying

To minimize the adverse changes occurring during dehydration and subsequent storage of mango, it is often necessary to apply pre-treatments before drying, as the dried fruits will continue to darken if they are not pre-treated before drying. Pre-treatments stop the metabolism of cut tissue either by killing cells or by injuring the enzymatic routes. Pretreatments are recommended techniques used to make quality products. They not only prevent darkening and improve quality; they also destroy pathogens that could cause foodborne illness (Adepoju *et al.*, 2021). Nguyen *et al.* (2024) stated that adequate pretreatment must be employed during the drying of mangoes, especially when drying them into powder. Various reports have also established that pretreatment could increase the drying rate by modifying the properties of the fruit tissue before drying, helping to shorten drying time, minimizing possible deterioration reactions during drying, reducing energy consumption, preserving the quality, and decreasing the microbial load of dried products (Citra *et al.*, 2021; Deng *et al.*, 2017). Different pre-treatment methods have been developed for fruit drying in general and for mango in particular. These include but are not limited to lemon juice treatment, ascorbic acid dip, salt solution, honey dip, sodium metabisulfite solution, calcium chloride solution, ultrasound pretreatment, sulfuring, osmotic pretreatment, sugar solution, and blanching (steam and water blanching) (Adepoju and Osunde, 2017; Bozkir *et al.*, 2019; Dereje and Abera, 2020; Mujumdar, 2006b; Mwende *et al.*, 2018). Though sulfuring or using a sulfite dip is regarded as the best pre-treatment for long-term storage of dried fruits, it may cause asthmatic reactions in a small portion of the population of people living with asthma.

6. Changes in the Proximate Qualities of Dried Mango

Changes do occur after drying of mango, either with or without pretreatments, especially in the proximate qualities of the dried mango. Adepoju and Osunde (2017) experimented on drying mango using three different pretreatments (ascorbic acid dip, honey dip, and steam blanching) on the mango slices and dried using sun, solar, and oven drying. They recorded varying degrees of changes in the proximate qualities of the dried mango samples, with the results of the analysis showing that there is no significant difference in the moisture contents of the dried mango samples. The moisture contents they obtained were within the safe moisture content for dried fruits and were lower than those obtained by Sanjinez-Argandoña *et al.* (2018) for osmotically pretreated mango dried in a convective air dryer and for dried date flour (Ekpo *et al.*, 2022). However, these moisture contents are higher than those obtained for dried papaya leaf powder using oven, freeze, and shade drying methods (Raja *et al.*, 2019). Adepoju and Osunde (2017) also observed that there were significant changes in the retention of the fat, protein, carbohydrate, and fiber contents of the dried mango slices, while there was no difference in the ash content. Another experiment was carried out by Mongi and Ngoma (2022) on the effect of solar drying methods on the proximate composition and other nutrients of different varieties of mango, and their findings portrayed different changes and retention levels of nutrients in dried mango. These observations indicated that different drying methods caused changes in the nutritional (proximate) values of the mango, though there was retention of these nutrients in the dried mango slices.

7. Changes in the Vitamin C And B-Carotene Contents of Dried Mango

Mango fruit is very vital in the human diet due to its vitamin content (Sayago-Ayerdi *et al.*, 2021; Yahia *et al.*, 2023). Drying of mango often leads to degradation of vitamins in the dried product. Adepoju and Osunde (2017) studied the effects of some pretreatments and drying methods on vitamin C and β-carotene contents and observed that mango samples treated with ascorbic acid and honey solution had greater values of vitamins C and β-carotene, followed by the steam-blanched samples, while the untreated samples had the least values. They concluded that pretreatments and drying methods affect the vitamin contents of dried mango samples. Sulistyawati *et al.* (2020)

also established that there were losses in vitamin C due to degradation and leaching when mango is preserved by osmotic dehydration. An experiment carried out by Dereje and Abera (2020) also recorded changes in vitamin C and other nutrients in mango in their study on the effect of pretreatments and drying methods on the quality of dried mango slices. Similar changes in vitamin C and β-carotene were documented for dried blanched papaya fruit (P. M. Nguyen *et al.*, 2019) and guava snacks obtained by convective, freeze, and refractance window drying methods (Leiton-Ramírez *et al.*, 2020).

8. Importance of Dried Mango

The importance of dried mangoes cannot be overemphasized because they have extensive usage in the food industry and can be a healthy addition to the human diet. When mangoes are dried, they yield products with extended shelf life, which can also be easily transported, thereby easy marketability of the product. The longer shelf life, compared to fresh mangoes, allows the fruit to be enjoyed even when it is out of season or when fresh mangoes are not readily available (Nowacka *et al.*, 2023). Dried mango slices may also be incorporated with probiotics either by direct impregnation with a probiotic suspension or coated with edible polysaccharide-based probiotics to produce healthy food options suitable for consumers with dietary restrictions to milk and derivatives (Niro *et al.*, 2023). Dried mangoes are nutrient-dense because they retain a good number of essential vitamins and minerals, which are crucial in supporting the overall health and well-being of the consumer. This, in turn, helps to fight against malnutrition in nutritionally insecure communities. Portable and convenient mango-based snacks that are lightweight, compact, and do not require refrigeration are made possible through the use of dried mangoes. These products are readily available and ideal for on-the-go travel or sports activities, where a quick energy boost is needed. Good quality dried mangoes can be exported or sold at better prices in the market, thereby increasing the economy of the farmers and the nation at large (Okaiyeto *et al.*, 2020). Dried mangoes are a good source of energy (because they contain concentrated fruit sugars), dietary fiber, and antioxidants. Dietary fiber aids in digestion, promotes satiety, and helps maintain regular bowel movements, while antioxidants, on the other hand, help to protect the body from oxidative stress caused by free radicals, thereby reducing the risk of chronic diseases. Therefore, the consumption of dried mangoes (and other fruits) makes healthy eating more practical and can help close the gap between recommended and actual fruit consumption (Ampah *et al.*, 2022; Chibuzo *et al.*, 2021). Another benefit of dried mangoes is their versatility and diversity of application in the food and confectionery industries. They can be used in various ways as ingredients in baked goods, trail mixes, granola bars, snacks, candies, or simply as a topping for salads, yogurt, or cereal. When rehydrated, dried mangoes can be used in recipes like chutneys or desserts (CBIMI, 2021).

9. Conclusion

Drying inevitably alters the nutritional profile of mango, particularly through moisture reduction and the loss of heat-sensitive vitamins. However, reports from numerous studies have established that not all nutrients are lost in the process; in fact, some compounds, such as sugars and dietary fibre, become more concentrated. Several factors come into play when mango is dried to facilitate nutrients' retention, including the choice of drying method, processing temperature, drying duration, and the application of pretreatments. Selecting appropriate techniques and conditions can therefore help minimize nutrient losses and preserve the desirable qualities of the fruit. Cost considerations also play a significant role, as accessible and energy-efficient drying methods are critical for widespread adoption, particularly in developing countries where post-harvest losses are high. Dried mango with high levels of retained proximate components and vitamins represents a nutritious, shelf-stable product that holds significant potential for both direct consumption and incorporation into the food, snack, and confectionery industries. Optimizing drying processes to balance cost, efficiency, and nutrient preservation is recommended for enhancing the versatility of mango along the supply chain and contributing to food security and industry growth.

References

Adepoju, L. A., and Osunde, Z. D. (2017). Effect of pretreatments and drying methods on some qualities of dried mango (*Mangifera indica*) fruit. *Agricultural Engineering International: CIGR Journal*, *19*(1), 187–194.

Adepoju, L. A., Osunde, Z. D., and Falua, K. J. (2021). Changes in Proximate Composition, Vitamin C and β-Carotene Contents of Oven Dried Pawpaw (*Carica papaya*) Fruit as Influenced by Pretreatment Methods. *FUOYE Journal of Engineering and Technology*, *6*(1), 10–14.

Ampah, J., Dzisi, K. A., Addo, A., and Bart-Plange, A. (2022). Drying Kinetics and Chemical Properties of Mango. *International Journal of Food Science*, *2022*, 1–13.

Bozkir, H., Ergun, A. R., Tekgul, Y., and Baysal, T. (2019). Ultrasound as pretreatment for drying garlic slices in a microwave and convective dryer. *Food Science and Biotechnology*, *28*(2), 347–354.

Caparino, O. A., Tang, J., Nindo, C. I., Sablani, S. S., Powers, J. R., and Fellman, J. K. (2012). Effect of drying methods on the physical properties and microstructures of mango (*Philippine "Carabao" var.*) powder. *Journal of Food Engineering*, *111*(1), 135–148.

Castillo Téllez, M., Castillo-Téllez, B., Hernández-Cruz, L. M., and Mejía-Pérrez, G. A. (2022). Solar drying study of mango (*Mangifera indica*) and determination of glucose content in dehydrated samples. *Journal Renewable Energy*, *6*(17), 1–7.

CBI Market Intelligence. (2021). The European market potential for dried mango. In the *Ministry of Foreign Affairs*. https://www.cbi.eu/market-information/processed-fruit-vegetables-edible-nuts/dried-mango/market-potential (accessed on 26 September 2022)

Chibuzo, N. S., Osinachi, U. F., James, M. T., Chigozie, O. F., Dereje, B., and Irene, C. E. (2021). Technological advancements in the drying of fruits and vegetables: A review. *African Journal of Food Science, 15*(12), 367–379.

Citra, F., Almira Aulia, G., Indiarto, R., Hodizah Asyifaa, A., Citra Angiputri Adiningsih, F., and Rahmalia Achmad, S. (2021). Conventional and Advanced Food-Drying Technology: A Current Review Article in. *International Journal of Scientific and Technology Research*, *10*(1), 99–107.

Deng, L. Z., Mujumdar, A. S., Zhang, Q., Yang, X. H., Wang, J., Zheng, Z. A., Gao, Z. J., and Xiao, H. W. (2017). Chemical and physical pretreatments of fruits and vegetables: Effects on drying characteristics and quality attributes–a comprehensive review. *Critical Reviews in Food Science and Nutrition*, *59*(9), 1–24.

Dereje, B., and Abera, S. (2020). Effect of pretreatments and drying methods on the quality of dried mango (*Mangifera Indica L.*) slices. *Cogent Food and Agriculture*, *6*(1), 1–24.

Ekpo, U. A., Nkechi, E., Tamuno, J., and Awajikatelem, O. (2022). Effect of Drying Methods and Variety on the Chemical Composition, Functional and Microbial Properties of Date Flour. *Research Square*, 1–17.

Food and Agriculture Organization of the United Nations. (2020). *Dried fruit*. 1–13.

Guiné, R. P. F. (2018). The Drying of Foods and Its Effect on the Physical-Chemical, Sensorial and Nutritional Properties. *International Journal of Food Engineering, 4*(2), 93–100.

Hussain, A., Kausar, T., Siddique, T., Kabir, K., An, Q. U., Rukhsar, F., Gorsi, F. I., Yaqub, S., Kauser, S., Rehman, A., Najam, A., Haroon, H., Rafiu, A., Korma, S. A., and Mahdi, A. A. (2024). Physiological and biochemical variations of naturally ripened mango (*Mangifera Indica L.*) with synthetic calcium carbide and ethylene. *Scientific Reports*, *14*(1), 1-12.

Kongpichitchoke, T., Gnoumou, E., Noomhorm, A., and Hsien, C. H. (2021). Study on Factors Affecting Physicochemical Properties of Spray Dried Mango Powder Using Taguchi Experimental Design Approach. *International Journal of Eco-Innovation in Science and Engineering*, *2*(1), 7–13.

Lebaka, V. R., Wee, Y. J., Ye, W., and Korivi, M. (2021). Nutritional composition and bioactive compounds in three different parts of mango fruit. In *International Journal of Environmental Research and Public Health* 18(2), 1–20.

Leiton-Ramírez, Y. M., Ayala-Aponte, A., and Ochoa-Martínez, C. I. (2020). Physicochemical properties of guava snacks as affected by drying technology. *Processes*, *8*(1), 1–12.

Manzoor, S., Yusof, Y. A., Ling, C. N., Tawakkal, I. S. M. A., Fikry, M., and Sin, C. L. (2019). Thin-layer drying characteristics of papaya (*Carica papaya*) peel using convection oven and microwave drying. *Pertanika Journal of Science and Technology*, *27*(3), 1207–1226.

Melesse, M. K., and Emire, S. A. (2022). Processing Effects of Drying Methods on Quality Attributes of Mango Chips. *International Journal of Food Science and Biotechnology*, *7*(3), 54–64.

Mohammed, S., Edna, M., and Siraj, K. (2020). The effect of traditional and improved solar drying methods on the sensory quality and nutritional composition of fruits: A case of mangoes and pineapples. *Heliyon*, *6*(6), 1–10.

Mongi, R. J., and Ngoma, S. J. (2022). Effect of Solar Drying Methods on Proximate Composition, Sugar Profile and Organic Acids of Mango Varieties in Tanzania. *Applied Food Research*, *2*(2), 1–7.

Mujumdar, S. A. (2006). Handbook of Industrial Drying. In S. A. Mujumdar (Ed.), *Taylor and Francis Group LLC* (Third Edit). CRC publishers. 1-464.

Mwende, R., Owino, W., and Imathiu, S. (2018). *Effects of pretreatment during drying on the antioxidant properties and colour of selected tomato varieties*, *6*(2), 503–511.

Nguyen, P. B. D., Nguyen, T. V. L., and Nguyen, T. T. D. (2024). Effect of Infrared Drying on the Drying Kinetics and the Quality of Mango (*Mangifera indica*) Powder. *Polish Journal of Food and Nutrition Sciences*, *74*(1), 69–81.

Nguyen, P. M., Tran, T. Y. N., Tran, D. B. L., Pham, M. N., and Phuong, N. T. T. (2019). Effect of Blanching and Drying on Quality of Dried Papaya Fruit. *Journal of Pharm. Sci. and Res.*, *11*(3), 1082–1086.

Niro, C. M., Mendonça, G. M. N., Paulino, L. R., Soares, V. F., and Azeredo, H. M. C. (2023). Freeze-Dried Banana Slices Carrying Probiotic Bacteria. *Foods*, *12*(12), 1–7.

Nowacka, M., Mannozzi, C., Dalla Rosa, M., and Tylewicz, U. (2023). Sustainable Approach for Development Dried Snack Based on Actinidia deliciosa Kiwifruit. *Applied Sciences (Switzerland)*, *13*(4), 1–16.

Okaiyeto, S. A., S. I., O., Unguwanrimi, Y. A., Jonga, B. J., and Sada, A. M. (2020). A Review of Dried Fruits and Vegetables Consumed in Northern Nigeria. *International Journal of Scientific Research and Management*, *8*(3), 66–72.

Omolola, A. O., Jideani, A. I. O., and Kapila, P. F. (2015). Quality properties of fruits as affected by drying operation. *Critical Reviews in Food Science and Nutrition*, *57*(1), 95–108.

Prangpru, N., Treeamnuk, T., Jaito, K., Vanmontree, B., and Treeamnuk, K. (2017). Effect of Temperature on the Physicochemical Properties of Tamarind (*Tamarindus Indica*) Powder. *International Journal of Food Engineering*, *3*(2), 127–131.

Radojčin, M., Pavkov, I., Kovačević, D. B., Putnik, P., Wiktor, A., Stamenković, Z., Kešelj, K., and Gere, A. (2021). Effect of selected drying methods and emerging drying intensification technologies on the quality of dried fruit: A review. *Processes*, *9*(1), 1–21.

Raja, K. S., Taip, F. S., Azmi, M. M. Z., and Shishir, M. R. I. (2019). Effect of pre-treatment and different drying methods on the physicochemical properties of *Carica papaya L.* leaf powder. *Journal of the Saudi Society of Agricultural Sciences*, *18*(2), 150–156.

Sanjinez-Argandoña, E. J., Yahagi, L. Y., Costa, T. B., and Giunco, A. J. (2018). Mango dehydration: influence of osmotic pre-treatment and addition of calcium chloride. *Revista Brasileira de Fruticultura*, *40*(4), 1–9.

Sayago-Ayerdi, S., García-Martínez, D. L., Ramírez-Castillo, A. C., Ramírez-Concepción, H. R., and Viuda-Martos, M. (2021). Tropical fruits and their co-products as bioactive compounds and their health effects: A review. *Foods*, *10*(8), 1–26.

Suherman, S., Hadiyanto, H., Trianita, A. P., Hargono, H., Sumantri, I., Jos, B., and Alhanif, M. (2023). Response surface optimization of time and pressure for freeze-drying mango slices. *Food Research*, *7*(1), 182–195.

Sulistyawati, I., Verkerk, R., Fogliano, V., and Dekker, M. (2020). Modelling the kinetics of osmotic dehydration of mango: Optimizing process conditions and pre-treatment for health aspects. *Journal of Food Engineering*, *280*, 1-16.

Techane, T. (2022). Effect of Ripening Stages and Drying Method on the Physico-chemical and Sensory Properties of Keitt Mango (*Mangifera indica L*) Sliced Chips. *Open Access Journal of Agricultural Research*, *7*(3), 1–10.

Teshome, B. (2010). *Effect of Processing on Some Quality Attributes of Mango (Mangifera Indica) Fruit Leather*. Addis Ababa University.

Tran, N. T. Y., Le, T. T. T., Nghia, N. H., Nhu, D. B., Huynh, L. B., Nguyen, T. X. T., Huynh, P. X., and Dao, T. P. (2023). Developing mango powders by foam mat drying technology. *Food Science and Nutrition*, 1–9.

Vera Zambrano, M., Dutta, B., Mercer, D. G., MacLean, H. L., and Touchie, M. F. (2019). Assessment of moisture content measurement methods of dried food products in small-scale operations in developing countries: A review. *Trends in Food Science and Technology*, *88*, 1–28.

Verma, A., and Singh, S. V. (2015). Spray Drying of Fruit and Vegetable Juices - A Review. *Critical Reviews in Food Science and Nutrition*, *55*(5), 701–719.

Verma, D. K., Thakur, M., Srivastav, P. P., Karizaki, V. M., and Suleria, H. A. R. (2020). Effects of Drying Technology on Physiochemical and Nutritional Quality of Fruits and Vegetables. In *Emerging Thermal and Nonthermal Technologies in Food Processing*, 69–116.

Yahia, E. M., Ornelas-Paz, J. de J., Brecht, J. K., García-Solís, P., and Maldonado Celis, M. E. (2023). The contribution of mango fruit (*Mangifera indica L.*) to human nutrition and health. *Arabian Journal of Chemistry*, *16*(7).

Zikri, A. H. B., Tien, B. Y., Hui, B. Y., and Han, W. K. (2022). Effects of processing parameters on the quality and properties of mango kernel flour: A mini-review. *Malaysian Journal of Analytical Science*, *26*(4), 742–754.