Conventional And Advanced Food-Drying Technology: A Current Review

Rossi Indiarto, Awwaliyah Hodizah Asyifaa, Fatsyarien Citra Angiputri Adningsih, Ghina Almira Aulia, Sarah Rahmalia Achmad

Abstract: Food drying techniques have long been applied since ancient times in conventional ways, such as drying in the sun or drying them. Currently, drying methods have been developed with the latest technology to reduce the damages caused by biochemical changes, which decrease nutritional value during the drying process. Some of the typical drying methods used for food products are sun drying, tunnel dryer, spray drying, drum dryer, freeze-drying, microwave drying, and fluidized bed drying. Meanwhile, the latest technology is developed to obtain the best drying results with various combinations of methods, including hybrid drying, superheated steam drying, refractance window, impingement drying, high electric field drying, or electrode hydrodynamic. This study will discuss the latest drying methods applied in food processing technology.

Index Terms: Drying, food, heating, moisture, physicochemical, technology

1. INTRODUCTION
Food spoilage refers to irreversible changes where food becomes inedible, or its quality is dangerous [1]. Food harm can be prevented or reduced by implementing food preservation techniques, one of which is drying. Drying is a process of removing water to prevent the growth of microorganisms, which can cause the decay process; also minimizes adverse reactions mediated in the presence of water [2]. The principle of drying is to remove water content in food by dehydration. Dehydration of food removes water from food by circulating hot air, stopping enzymes, and microbes’ activity [3]. Food drying techniques have long been applied in conventional ways, such as drying in the sun or through the blowing wind [4]. These methods are still used today because they are considered more economical and efficient by utilizing natural energy with unlimited energy. However, this method’s drawback is the instability of power from nature, which affects the drying rate. Drying also tends to take a long time and allows for significant degradation of nutrients and bioactive compounds. Various attempts have been made to develop drying techniques to reduce moisture content and minimize bioactive components’ degradation caused by biochemical changes and decrease nutritional value during the drying process [5]. The development of drying technology in the last few decades has been very rapid, including the pretreatment process, techniques, equipment, and the quality of the final product produced [6], [7]. All of these methods have different principles and mechanisms and have their respective advantages and disadvantages. This review aims to learn more about the drying methods applied in the food processing process, from conventional to modern forms.

2. DRYING PRINCIPLE IN FOOD
The process of drying food involves the process of changing the form of water in food to gas. Then remove it from the food so that it becomes dehydrated. Drying is a dehydration process to eliminate water in food products using heat obtained from hot air or solar energy. Water removal must be achieved in minimal conditions to damage product quality [6]. The dehydration process was developed to maximize the use of conditions in the raw materials and energy sources used [8]. Except for freeze-drying, heat transfer during drying can be carried out through conduction, convection, and radiation to push water to evaporate. Meanwhile, the air is used to encourage vapor removal [9].

3. DRYING METHODS ON FOOD PRODUCTS
3.1 Sun-drying method
Sun drying is a way to dry agricultural products using direct sun exposure [10]. This method has the advantage of saving costs and energy. However, as it uses natural power, it is highly dependent on weather changes that tend to be erratic [11]. The sun-drying method is generally used in tropical areas with at least 6 hours of sunlight received as much as 500-800 W/m² radiation per hour, resulting in 185 W/m² day isolation [12]. Drying peppers by sun-drying is done using an even surface exposure that can last for a week. The average temperature is 20-37 °C [13]. Then, drying mango and wild bean leaves in direct sunlight showed reduced moisture content of up to 10-15% [14]. Table 1 shows the characteristics of sun-dried food products in various studies.

<table>
<thead>
<tr>
<th>Table 1. Various characteristics of sun-dried foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
</tr>
<tr>
<td>Grapes</td>
</tr>
<tr>
<td>Indian red chili</td>
</tr>
<tr>
<td>Germinated brown rice</td>
</tr>
<tr>
<td>Chitosans</td>
</tr>
<tr>
<td>Takuan-zuke (pickled daikon)</td>
</tr>
<tr>
<td>Shrimp</td>
</tr>
</tbody>
</table>

3.2 Tunnel drying method
This tunnel dryer passes through the transparent flat collector plate, series-connected to directly supply heat energy to the tunnel dryer, using 4 DC fans [21]. It is commonly used industrially to dry horticultural and fishery products. A tunnel dryer uses solar thermal energy. It is more effective than sun-drying, but it's difficult to predict because it's weather dependent [22]. In the process of drying the grapes with a tunnel dryer, the grapes are dried at a temperature of 10-28 °C.
in sunny weather and closed tunnel dryer with semi-transparent polyethylene sheet 200 μm thickness. After going through the drying process, the wine will reach a moisture content of 16% wb [23]. Drying salted fish using a tunnel dryer is done first, with the fish given salt for 16 hours. The voltage used is in stages from 7.0 to 14 V. The process will end after the fish's water content decreases to 16.78% wb [21]. Table 2 shows the characteristics of tunnel-dried food products in various studies.

Table 2. Various characteristics of tunnel-dried food products

<table>
<thead>
<tr>
<th>Product</th>
<th>Characteristics</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>The water content decreased from 85.5% (wb) to 12.0% (wb) in 9.5 hours</td>
<td>[24]</td>
</tr>
<tr>
<td>Tomato</td>
<td>Water content decreased from 91% (wb) to 7.1% (wb) in 10 hours</td>
<td>[25]</td>
</tr>
<tr>
<td>Chilli</td>
<td>Reduces moisture content up to 98.25% for 20 hours</td>
<td>[26]</td>
</tr>
<tr>
<td>Grape</td>
<td>Water content decreased by up to 16% for 7 days</td>
<td>[23]</td>
</tr>
<tr>
<td>Aonlía pulp</td>
<td>Water content decreased from 424.93% (db) to 10.08% (db) for 16 drying hours</td>
<td>[27]</td>
</tr>
<tr>
<td>Fenugreek leaves</td>
<td>Decreased water content from 89% (wb) to 9% (wb) for 17 hours</td>
<td>[28]</td>
</tr>
</tbody>
</table>

3.3 Spray drying method

Spray drying is often used for heat-sensitive processes in the food industry [29]. Its method has lower specific energy consumption than the freeze-drying way [30], [31]. Spray drying to convert a solvent, emulsion, or suspension material into a solid product. The principle of this spray drying process will be continuously pumped into the atomizer and divided into fine droplets in the chamber. Its droplets formed will come into contact with hot air by convection, providing heat energy to evaporate most of the solvent in droplets to form a powder particle [32]. Spray drying has the advantage of having relatively low operating costs and a short drying process. However, in this drying method, high temperatures are used so that in drying food containing protein, for example, egg white, it will reduce the quality of egg white protein [29]. Spray drying is commonly used in encapsulation because it is faster, flexible, low-cost, produce microparticles of good quality, and allows for scale-up [33]. Lucas et al. [33] state that encapsulating oleoresin turmeric curcumin with a spray dryer stabilizes the product and provides a long shelf life. Liu et al. [29] research conducted a spray drying process on hydrolyzed ovalbumin preparation where the resulting product's characteristics have emulsifying activity, higher protein solubility, and foaming capacity. Hoskin et al. [30] research conducted a spray drying process on blueberry pomace containing polyphenols. Spray drying was used to produce blueberry-polyphenol foods with phytochemical preservatives and biological activity. Table 3 shows the characteristics of spray-dried food products in various studies.

Table 3. Various characteristics of spray-dried food products

<table>
<thead>
<tr>
<th>Product</th>
<th>Carrier</th>
<th>Characteristics</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish oil</td>
<td>Hydroxypropyl cellulose</td>
<td>Fish oil-microparticles with methanol showed maximum oil stability during storage</td>
<td>[34]</td>
</tr>
<tr>
<td>Curcumin</td>
<td>Inulin, modified</td>
<td>Improves the stability of heat</td>
<td>[35]</td>
</tr>
</tbody>
</table>

3.4 Drum drying method

Drum drying is a drum that rotates continuously and is heated. Drum dryers have high drying efficiency, with a heat energy efficiency of 60-90%, and low operating costs [14]. In operation, the material in the form of a liquid, slurry, or dried dough is fed to the rotating drum's outer surface to form a thin layer of about 0.5-2.0 mm covering the drum surface. The drum's surface temperature is very high because steam heats the drum inside. Condensate vapor, raising the temperature and heating the slurry through drum wall conduction. Drum drying time is related to rotating drum speed [39]. The heat transfer rate in drum drying occurs on the drum controller's entire surface in the drying process [14], [40]. A thin layer of material attached to the hot drum's surface will rapidly experience an increase in temperature and water evaporation, resulting in simultaneous cooking and drying. Because only a few seconds are exposed to high temperatures, drum drying is very suitable for most heat-sensitive products [14], [41]. Drum-dried foods include powdered milk, cereals, applesauce, fruit puree, fruit powder, dry soups, baby food, and other food products. This dryer is also suitable for potato starch [13], [42]. The starch granule structure breaks down in this drying process, increasing product solubility and water absorption. It also uses drying drums to form skinned milk powder. However, research on drying skim milk powder using a drum dryer in Aalaei et al. [43] showed higher lysine losses than freeze-drying. It's a drum-drying method drawback. Henríquez et al. [14] performed drying to determine the degradation kinetics of total polyphenol content in apple skin. Olsen et al. [13] also served drum drying on high-water pomace fruits and vegetables. Table 4 shows the characteristics of drum-dried food products in various studies.

Table 4. Various characteristics of drum-dried food products

<table>
<thead>
<tr>
<th>Product</th>
<th>Characteristics</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riceberry flour</td>
<td>Drum drying may be used to pregelatinize riceberry flour</td>
<td>[44]</td>
</tr>
<tr>
<td>Red cabbage</td>
<td>Can be used for encapsulation with high anthocyanin efficiency</td>
<td>[45]</td>
</tr>
<tr>
<td>Rye</td>
<td>Efficient to reduce deoxynivalenol, nivalenol, and zearalenone producing Fusarium culmorum</td>
<td>[46]</td>
</tr>
<tr>
<td>Pomegranate peel</td>
<td>Drum drying at 100–110°C retains hydrolyzed tannin content</td>
<td>[47]</td>
</tr>
<tr>
<td>Apple skin</td>
<td>Polyphenols are degraded</td>
<td>[14]</td>
</tr>
<tr>
<td>Skim milk</td>
<td>There was a decrease in lysine with an average</td>
<td>[43]</td>
</tr>
</tbody>
</table>
**3.5 Freeze-drying method**

Freeze-drying is a process that sublimates water after frozen. The food and pharmaceutical industries are commonly used to produce dry products by preserving their bioactive components [48]. Lyophilization is another freeze-drying term. It processes includes three stages: freezing, primary drying, and secondary drying. The ingredients are processed at low temperatures until freezing. The primary drying principle is sublimation. Sublimation is a direct change from solid to gas without initiating the liquid phase, where ice changes directly into vapor. Therefore, the dried product must be less than or near the frozen solvent’s equilibrium vapor pressure [49], achieved using a vacuum pump [50]. The primary drying stage is -10°C or less at 2 mmHg absolute pressure or less to keep water in the freezing phase [51]. When the water is sublimated, it will shrink from the outermost layer and leave a porous shell that is a dry product. The latent heat from sublimation is conducted through the dry and frozen layers, while steam is transported through the dry matter’s porous layers. The end of freeze-drying is marked by no more frozen layer being removed, meaning no more surface for sublimation [52]. Secondary drying uses the desorption principle. Desorption involves removing water that is not frozen, also known as bound water. Secondary drying starts at the end of primary drying. The desorbed water vapor is transported through the dry matter pores [49]. This stage aims to reduce the moisture content to the best possible level. It provides stability because the product still contains 10-35% bound water after the sublimation process. The moisture and porous media adsorption-desorption balance are the essential secondary drying factor. So that temperature and moisture content must be controlled to get excellent product quality [53]. The application of freeze-drying on several food products changes the characteristics of the products produced. Changes that occur include components such as bioactive compounds, aroma, shrinkage, and rehydration of the product during the process [54]. Broccoli treated with vacuum freeze-drying experiences changes in total polyphenols and antioxidant activity due to the freezing rate [55]. Treatment with atmospheric freeze-drying also causes changes in the total phenolic compounds due to particle size, freezing rate, and irradiation [55], [56]. However, the total polyphenol and selenium levels were higher than the vacuum freeze-drying results [55]. Fruits also work well for freeze-drying [57]. Various studies have shown that freeze-drying on fruits such as star fruit, mango, papaya, watermelon, and cantaloupe showed that they did not significantly change ascorbic acid levels. Likewise, beta-carotene levels can also be maintained, except for mango and watermelon samples. However, there is a significant change in total phenolic compounds, so that freeze-drying is concluded to change the antioxidant activity of these fruits [58]. Apart from nutritional activity, freeze-drying also has an impact on the physical properties of ingredients. The bulk density of products such as undercooked rice and fresh agricultural products such as freeze-drying rice, strawberries, and mushrooms increases with increasing pressure in the freeze-drying process, while porosity decreases [59]. Whereas for apples, bananas, carrots, and potatoes, the same results showed that the bulk density increased, and the final porosity decreased with increasing temperature. The porosity ranges from 70% to 95%. The final porosity is associated with a decrease in frozen apples and potatoes' complex viscosity, directly proportional to the temperature increase [60]. The freeze-drying is advantageous because it can minimize the loss of volatile compounds, heat-sensitive nutrients, and aroma compounds. The preservation effect of the low temperature used is the inhibition of microorganisms’ growth and enzymatic reactions to minimize changes in foodstuffs’ properties. This process can remove 95.0-99.5% of water. Also, due to the use of vacuum pressure, this method protects compounds that can be oxidized. The entire aseptic freeze-drying process can maintain product sterility and minimal contaminants [50]. From the aspect of sensory properties, freeze-drying can increase the brightness of the color and produce a crunchy, soft, creamy texture, and crumbles easily on the tongue [61]–[63]. One of the most significant obstacles for the industry to use freeze-drying is cost. Freeze drying is one of the most expensive operating units to produce dry products with high energy consumption and increased operation and maintenance costs. Another disadvantage is that the high vacuum pressure can remove some volatile compounds. There are several issues related to the guarantee of sterility in the drying room and the process of transporting the tubes into the drying room [50]. Table 5 shows the characteristics of freeze-dried food products in various studies.

### Table 5. Various characteristics of freeze-dried food products

<table>
<thead>
<tr>
<th>Product</th>
<th>Characteristics</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange Puree</td>
<td>Capable of maintaining nutrition, especially vitamins C and β-carotene, with a crunchy texture</td>
<td>[64]</td>
</tr>
<tr>
<td>Citrus by-product extracts</td>
<td>Freeze dryer moisture content is lower than dryer spray to encapsulate citrus by-product extracts.</td>
<td>[65]</td>
</tr>
<tr>
<td>Starch hydrogel</td>
<td>Freeze drying causes decreased starch gel's uniform, crystalline structure. High amylose-starch gel resists damage during drying</td>
<td>[66]</td>
</tr>
<tr>
<td>Garlic</td>
<td>Pretreatment cycle freeze-thaw before freeze-drying reduces drying time and energy consumption; improves thermal stability and quality of garlic products; increases antioxidant activity</td>
<td>[67]</td>
</tr>
<tr>
<td>Watermelon, mango</td>
<td>No significant change in ascorbic acid levels, but significant changes in β-carotene and phenolic compounds</td>
<td>[58]</td>
</tr>
</tbody>
</table>

**3.6 Microwave drying method**

Microwaves are electromagnetic waves ranging from 1 mm to 1 m, with 0.3 GHz to 3.0 GHz frequency ranging. These frequencies are more extensive than radio waves. The microwave penetrates the food inside, causing water to heat inside the ingredients. It increases the vapor pressure differential between the center and surface of the product, allowing a rapid transfer of moisture from the material [68], [69]. Microwave-to-medium interaction causes heat. Electromagnetic energy is dissipated and converted volumetrically into heat. The mechanism to change this energy form depends on the medium’s characteristics and wave frequency [70]. Radiation from the microwave on drying or heating is retained in the cavity. The heat lost through convection is so small that the cavity material generally absorbs energy. In principle, this energy is absorbed by the water in the material, causing an increase in temperature, evaporation of a certain amount of water, so a decrease in moisture content [71]. Microwave oven applications on food are used at 2450 MHz (12.24 cm wavelength). Water, fat, and sugar molecules in food absorb microwave radiation energy by
heating the dielectric. Most water molecules are electric dipoles, which means they have a positive and negative charge. Hence, they rotate as they adjust to the changing electrical fields caused by microwave radiation. The movement of this molecule will generate heat from rotating molecules that collide with other molecules. Microwave drying less effective for fats, sugars, and ice because of fewer dipole moments, so the molecules rotate harder [71]. Microwave drying cannot be a single drying operation unit in its application. It must be accompanied by other drying operations such as hot air dryers [72], vacuum dryers, and multi-flash dryers [73], [74]. It can also be combined with freeze-drying (Microwave-Freeze Drying) [54]. The microwave is applied to reduce drying time and shrinkage [75]. Vegetables often use microwaves for drying. Such carrot drying was reported to produce the highest total solids, the fastest drying time, and maintain significantly higher shrinkage than hot and infrared drying methods. Microwave drying performed better to protect materials from discoloration [76]. Microwave drying also affects the color, appearance, and aroma of amaranth, dill, fenugreek, mint, and coriander. But this method not suitable for mint and coriander [77]. The strawberry fruit commodity resulted in minimal color change and decreased texture hardness after microwave-vacuum dried. The shelf life of strawberries can reach 68 days, with anthocyanins as the most unstable storage component [73]. Vacuum microwave drying consisting of microwave-vacuum drying and microwave-freeze drying produces dry and crunchy products with large pores and high porosity on pumpkins [78]. It was also reported that microwave-freeze drying had larger pores and 20-50% higher porosity than microwave-vacuum drying [74]. However, ginger microwave drying caused browning and tissue damage, which increased with microwave temperature and power. Meanwhile, the rehydration ratio's ability decreases with increasing drying temperature [79]. Microwave can reduce drying time by 25-90% [80], [81] and increase drying rate 4-8 times [82] compared to conventional drying. Microwave drying can also result in better uniformity and use energy more efficiently. One of the reasons is because power is directly paired with humidity, so that the need to transfer heat from low-humidity surfaces to high-humidity insides can be eliminated. Increased movement of moisture transfer causes energy efficiency owing to the high internal vapor pressure [75]. In microwave drying, heat and mass transfer are not well controlled to produce excess heat that damages the product [69]. However, case hardening can be reduced or avoided due to moisture accumulation's uniqueness on the material surface and the liquid pumping phenomenon when food is microwave-dried [83], [84]. Microwave drying up to 60 times faster than regular drying is also reported to damage the biomass surface in rice, sugar cane, grain, and cotton to release many volatile compounds and reduce the crystallization ability of rice stalks, sugar cane, and grain [85]. Table 6 shows the characteristics of microwave-dried food products in various studies.

Table 6. Various characteristics of microwave-dried food products

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Characteristics</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranberries</td>
<td>Increase bioactive cranberry compounds resulting in high fruit antioxidant activity</td>
<td>[86]</td>
</tr>
<tr>
<td>Balsam pears</td>
<td>Microwave drying may retain standard aroma and minimize burnt aroma</td>
<td>[87]</td>
</tr>
<tr>
<td>Persimmon chips</td>
<td>It can improve rehydration, preserve color and texture, have the best sensory chip score</td>
<td>[88]</td>
</tr>
<tr>
<td>Cocoa pod husks</td>
<td>Increase bioactive compounds and antioxidant activity</td>
<td>[90]</td>
</tr>
</tbody>
</table>

3.7 Fluidized-bed drying method

The various drying techniques developed have succeeded in providing uniform moisture content for drying results, and the process is faster. Fluidized-bed drying is one such technique. For specific food drying, fluidized bed dryers ensure high heat intensity, mass transfer, and increased drying rates [91]. The dryer consists of an airflow blower, fluidized column, and electrical heating and temperature control [92]. This dryer's drying room is filled with the material to dry. Hot air with some pressure and volume pushes the product to dry until its weight gets lighter. Fluidized bed dryers are widely used for drying wet particles, fluidizable granular materials, slurries, and pastes [93]. Many fruits, vegetables, cereals, or agricultural products like rice and maize are dried using this fluidized bed drying method. Its benefits include mixing solid materials, efficient heat and mass transfer, fast and economical drying, easy regulation, temperature uniformity, and comfortable material handling and transfer [94]. While the lack of energy efficiency is less than 50%, product quality such as color, texture, flavor, and nutritional components is losing [9], [92]. Table 7 shows the characteristics of fluidized-bed dried food products in various studies.

Table 7. Various characteristics of fluidized-bed dried food products

<table>
<thead>
<tr>
<th>Product</th>
<th>Characteristics</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown algae</td>
<td>Provides greater yield total production than other drying methods</td>
<td>[95]</td>
</tr>
<tr>
<td>Shelled corn</td>
<td>The moisture content of the solids decreases with increasing temperature of the incoming air, while the moisture content of the solids increases with increasing the mass flow rate of dry solids</td>
<td>[96]</td>
</tr>
<tr>
<td>Soybean kernels</td>
<td>The percentage of cracked increased at higher drying temperature, air velocity, and drying time.</td>
<td>[97]</td>
</tr>
<tr>
<td>Paddy</td>
<td>Using 40–150 °C inlet air temperature does not affect rice quality. Rice milled quality is also well-preserved.</td>
<td>[98]</td>
</tr>
<tr>
<td>Citrus sinensis Peels</td>
<td>Fluidized bed drying can retain vitamin C and limonene content better than sun drying. It can also reduce microorganism growth, increasing shelf life</td>
<td>[99]</td>
</tr>
</tbody>
</table>

4. DEVELOPMENT OF CURRENT DRYING METHODS

Research development resulted in a drying method that focuses on improving existing drying weaknesses to produce quality products and has high energy efficiency, such as freeze-drying, microwave vacuum, microwave-freeze drying. There are also two spray-freeze drying methods combined. What will be discussed here, however, are innovative methods to dry the latest generation. Superheated steam drying is regarded as an innovative way to dry food ingredients. This method involves applying hot steam to food at a temperature above its boiling point and absolute pressure [100]. Superheated steam drying of whole wheat has advantages, such as significantly reducing the yield of total plate counts and reducing enzyme activity (lipase, lipoxygenase, and polyphenol oxidase) flour. It also extends shelf life, inhibits damage, and stabilizes semi-dry whole wheat noodles' storage.
quality. At a temperature of 155-170 °C, this method can improve wheat flour’s thermomechanical properties [101]. Refractance Window is a current drying technique for transforming liquid food and other biomaterials into added-value powders, flakes, or sheets. Slurry or juice products made from fruits, vegetables, or herbs are dried in this system for a short period; usually, 3–5 minutes, to produce a product with excellent color, vitamins, and antioxidant retention. Refractance window drying systems are simple and relatively inexpensive to freeze-drying, requiring large installations to be economical. This drying system transfers heat energy from hot water to materialize. Then it is spread evenly on a thin transparent material or polyethylene film heated and placed on the water surface. Films can move or be stationary if they move in a conveyor system; food ingredients generally move to hot water in the opposite direction [102]. At atmospheric pressure, the drying system works. The application of this method to mango pulp shows good performance. It is advantageous, where 5% less of the total thermal energy is contributed by radiant heat transfer [103]. The refractance window shows good performance in drying pepper color quality [104]. It is also used to produce a mixture of scrambled eggs, avocado powder, carotenoid-high algae, herbal extracts, and human nutritional supplements, food ingredients, and dried fruit and vegetables for commercial production. Impingement drying is when the dry material is treated with high-speed hot air flowing back to the dryer. High heat transfer coefficient and reduced drying time allowed for more efficient drying [105]. According to Wenfeng et al. [106], this method may significantly reduce total phenolic content, ascorbic acid, and DPPH radical scavenging activity in onions. However, these results are better than conventional drying in drying time and increased drying rate [106]. High electrical field drying or electrohydrodynamic drying involves using AC-DC current at high intensity and standard frequency to remove moisture from the sample drying process. Both methods are included in convection drying techniques to remove water and retain bioactive heat-sensitive compounds in food [107]. Electrohydrodynamic drying of sea cucumbers (Stichopus japonicus) is reported to have several advantages: less shrinkage, better rehydration, more protein content, and energy savings [108]. Another non-thermal drying example is ohmic drying. Each food ingredient has its electrical conductivity [109], [110]. Ohmic heating uses the electrical conductivity found in food to generate heat when electrical energy is passed on to food [111]. This method’s advantage is that it can save power up to 82%-79% and reduce heating time by 90%-95% [112]. However, several disadvantages include high food costs and lipid content that may affect electrical conductivity [113].

5. CONCLUSION
In general, food drying has several methods: sun drying, tunnel drying, spray drying, drum drying, freezing, microwave drying, fluidized bed drying. Technology and research are developing to create the best drying method that produces high-quality dry products and is more energy-efficient. Some of the technologies often used include mixed/hybrid drying methods, superheated steam drying, refractory window, impingement drying, high-electric field drying, electrohydrodynamic drying using electrotechnology, and ohmic drying.

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