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Infrared radiation drying application in agriculture

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Abstract

World agricultural products, in general, are very diverse, and Vietnam is no exception. In the current trend, high quality agricultural products are increasingly receiving attention and modern methods are applied to improve their quality. Among many methods for improve quality, the infrared radiation drying method is evaluated to minimize drying time, reduce deterioration of agricultural product quality and limit environmental impact. Therefore, this article focuses on applying infrared radiation drying method to agricultural products composed of seafood. The article describes and compares the technical conditions when drying plants and animals using the infrared radiation drying method in combination with other drying methods.

Keywords: Application; Agriculture; Drying; Infrared; Radiation

1. Introduction

In processing and preserving agricultural and food products, drying is one of the necessary stages, affecting productivity, quality and determining the price and shelf life of goods when brought to market. Industrial dryers will help the product drying process be thorough and effective, improving productivity and quality. To help businesses and production facilities choose appropriate drying technology that is low cost, safe for users, and environmentally friendly. Infrared radiation drying technology is a method of drying moist materials using heat emitted from infrared rays as the mainly agent to evaporate water in food. Infrared rays are electromagnetic radiation with wavelengths thicker than visible light, with electromagnetic wavelengths ranging from 0.76 - 1,000μm.

Infrared dryer is arranged with infrared light bulbs inside the drying chamber. These light bulbs will emit radiant energy continuously with high intensity. Infrared drying lamp has a tungsten filament, lamp capacity ranges from 150 - 500 W/h, drying temperature (radiation) is adjusted from 30-150 °C; Drying time is from (6-12) hours depending on the type of drying material; Adjustable radiation intensity (0.25-10.5)kW/m^2 has quite simple structure, simple usage and operation. The heat transfer ability and heat transfer rate into the product of these types of infrared drying lamps depends on three factors: The external temperature of the heat-emitting bulb and the heat-receiving object, the surface properties and shape of the bulb. The lamp and product receive heat.

Therefore, this article focuses on infrared radiation drying on different materials with analysis and comparison.

2. Material and methods

The method of overview, expert, analytical and speculative are applied in this study. Studying materials are published documents on infrared radiation on plants and animals.

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3. Results and discussion

Thermal drying of infrared radiation (IRD) has many advantages compared to other methods (conduction and convection), such as reduced heating time, uniform temperature distribution, reduced product quality loss, flexibility in zone heating, the simple device, compact, and saves energy [1]. IRD is used for different food processing processes, for example, drying, baking, blanching, steaming, and pasteurization [2]. IRD assist to other heating methods (microwave, conduction, and convection) will increase energy efficiency. In addition, IRD is very successfully to dry vegetables such as potatoes [3], sweet potato [4], onion [5], kiwi fruit and apple [6], vegetables, meat, fish, pasta. IRD has also been used to analyze moisture content in food products [7]. Factors affecting the drying kinetics of potato chips have been noticed [8] that the drying speed increase of potatoes depend on increasing the surface temperature of the radiation source. In the dried shrimp with IRD, the effect of radiation distance is not as important when the radiation plate and the air temperature are increased [9].

IRD has the advantage of fast drying time, and its heat is formed from inside the drying material, but penetration is limited [10]. Irradiation of biological materials with IRD for a long time causes the material to swell and crack [11]. IRD heat changes the physical, mechanical, chemical properties and other functions of barley grains [12]. Dried beans with IRD at 140 ^{o}C causes cracking on the product surface [13]. Combining IRD with convection for thick, porous materials by intermittent drying will cause energy efficiency and dried product quality higher [14]. Studies by Pramod et al. (2022) [15] have shown that drying apple slices by IRD is much more effective and faster than drying by convection at the same drying mode. During drying onions using air convection-assisted IRD, Sharma et al. (2005) [5] noticed that the drying time was prolonged as increasing the air speed. The drying time will reduce as increasing IRD energy and drying surface area.

The combined drying application of IRD and convection will be more effective than using only IRD or simple convection. Afzal and CS (1999) [16] showed that in the drying process of barley using the convection combined IRD, the total energy demand will be reduced by 156%, 238%, and 245%, respectively, compared to convection drying at temperatures of 40, 55, and 70°C, respectively. Daniel et al. (2019) [17] also applied a combination of IRD drying, microwaves, and hot air convection for food ingredients. Salam et al. (2019) [18] used radiant heat from ceramic rods into a vacuum drying chamber to dry onions. The development in belt dryers using IRD and hot air sources-assisted IRD will reduce drying costs, time and temperature. However, the thickness of vegetables should be not more than 5mm to increase drying efficiency [19]. Umes et al. (2004) [20] developed a conveyor vegetable dryer that combines infrared and convection. This combination causes the material to be quickly heated, has a high mass transfer rate, reduces drying time by 48% and saves 63% of energy consumption compared to conventional convection drying.

Recently, the use of IRD immediately after convection drying of rice (at approximately 40 ^{o}C) has been applied in the Japanese rice industry. Michael et al. (2006) [21] compared the quality criteria of dried onions under IRD and hot convection air, and the results showed that using IRD conbination had the highest drying rate and short drying time. The color formation during baking of red beans under IRD was studied by the previous notices. Rashid et al. (2019) [22] discovered the color formation of bread by higher IRD heat and shortened time compared to conventional ovens. Furthermore, the rapid formation of colors, in addition to the effect of IRD, also has the effect of heat. The water loss rate is fast, the heat transfer rate is high, but the total water loss is less due to the short heating time.

In general, the formation of a hard crust will be thinner when baking bread with IRD. Drying by convection-combined IRD or vacuum drying-assisted IRD has been studied by many scientists. The combination has been shown to be more effective than drying by alone IRD or drying by convection hot air. In 1999, Afzal et al. [16] concluded that the drying process using hot air-combined long-wavelength IRD results in faster drying and consumes less energy than when drying with convective hot air alone. However, the drying process combining IRD with freeze-drying has also been studied on potatoes. When IRD is used to dry fruit, radiation will penetrate inside and convert into heat through the movement of molecules. Radiant energy penetrate on the material depends on the composition and the structure of material and its wavelength. IRD energy penetrates into the food and is converted into heat energy, thus creating a very fastly heating mechanism. Radiant energy is absorbed directly into the material, so its loss into the environment is low. The drying speed of raw materials using IRD is higher than the convection drying method with hot air and increases with increasing IRD intensity. IRD heats more uniformly and gives better quality than other methods.

In 2008, study of Supawan et al. [23] exhibited drying dried shrimp using infrared heat combined with convection technology. Two shrimp sizes of 100 shrimp and 200 shrimp/kg got an initial moisture content of 270-350% (d.b) dried to a moisture content of 20-25% (d.b). Zhongli et al., studying the dehydration process of continuously dried bananas using IRD and freeze-drying, showed that removing water from sliced bananas using IRD, the drying rate was significantly higher than when drying with hot air-assisted IRD. The ratio will increase with the increase in radiation intensity. However, this study showed that banana slices pre-dehydrated with IRD dried more slowly during the freeze-drying process than samples without dehydration due to structural changes that occurred during the dehydration process [24]. Zhongli et al. studied drying onions using infrared drying and showed that drying efficiency was better than forced air convection. The drying temperature for infrared method are 70 ^oC and 80 ^oC. Temperature 80 ^oC should be used at the beginning of the drying process to achieve maximum drying while minimizing damage. If using a convection drying system combined with IRD, it will dry IRD in the first stage and force convection drying in the later stage [24]. Damir et al. studied on the dehydration process of celery using IRD at temperatures of 50 ^oC and 75 ^oC. The results showed that dehydration time depends on the content of volatile components in the celery samples. West, that is, the higher the content of these components, the longer the time to remove them. At 75 ^oC, water removal time decreases because the moisture diffusion process increases. For blanched celery samples, the dehydration time is longer than for fresh celery samples of the same size [25].

Mohammad et al. used heat pump drying (HPD) combined with FIR to dry sliced papaya, galingle and lemongrass. Experimental results show that the 55 ^oC drying mode is the combined drying method. HPD-FIR provides product quality with good sensory quality, uniform product moisture, and reduced drying time. Specifically, with sliced papaya, drying time has been reduced compared to heat pump drying that cannot incorporate infrared, up to 4 hours, energy consumption SEC=4.91 MJ/Kg H_2O, heat pump coefficient is 3.56 [26]. Pääkkönen [27] showed that when drying medicinal plants such as mint, Agastache foeniculum L., parsley (Petroselinum crispum L.) and angelica (Anglica archangelica L.) in drying mode at 35-50 ^oC with different drying methods including infrared, microwave and hot air convection, the potential of IRD for herbs is better than the two control methods.The infrared drying time is less than other drying, and the product moisture is uniform more. On the other hand, the total microbial indicators, total yeast and mold counts of products dried by microwave and infrared are significantly improved compared to convection drying.

Studies by Taner Baysal et al. on the effects of microwave drying and IRD on the quality of carrots and garlic have reached conclusions. The color of the food changes during the drying process, but when dried with hot air, the color of the carrot is most similar to the fresh carrot sample, but the rehydration ability is lowest. Meanwhile, the infrared drying method has the highest water absorption ability. When evaluating the dry matter content of carrots, microwave-dried carrot samples had significantly high dry matter content with the shortest drying time and high shrinkage. The results showed that the characteristics of quality product vary depending on the drying method. For garlic, in the dehydration process, except for color, differences were found non significant between the three drying methods (hot air, microwave and infrared drying) [28]. Le Van Hoang has implemented the IRD projection method with air convection (speed of 1.14-1.24 m/s) to dry rice before storage. Research shows that the longer the exposure time and the shorter the projection distance, the more the cracking increases. At a distance of 330mm, the temperature affecting the surface of the grain is < 50 ^oC, and it only takes 10-15 minutes of exposure for the grain's moisture to reach equilibrium moisture (corresponding to ϕ=70%), cracking increases from 0.7% to 0.9% [29].

In 2001, Do Thi Bich Thuy studied the cracking rate of rice seeds before and after drying using IRD. Although the seeds were exposed to higher temperatures than the sun-drying method, due to the quick reaction time, the rate was higher, lower grain cracking. The has great significance in contributing to reducing post-harvest losses. During the first 15 minutes of exposure, the germination rate decreased but not significantly (about 2%), but with prolonged exposure time, the germination rate decreased significantly (after 30 minutes decreased by 16%). The should be kept in mind when using IRD to preserve varieties. The research results on the effect of exposure time on the mortality rate of insects were carried out on rice samples with a density of 62 insects/kg, taken in storage, with a thickness of the experimental grain layer of 1cm. projection 49-50 ^oC. Most types of rice weevils have gray to dark brown outer shells. Therefore, they easily absorb infrared rays, and quickly get heated within the first 10 minutes having about 75% die. Continue showing for another 5 minutes where the insects are barely alive. The proves the advantage of IRD in the insect elimination during food preservation [30]. Applied research on selective narrowband IRD technology to dry other agricultural products such as rice, corn, coffee, tomatoes, zucchini noticed that the time drying has been significantly reduced compared to conventional drying methods. For example, the color and flavor of the product has been improved, and the ability to kill microorganisms and harmful insects in agricultural products and foods are better with selective IRD.

In 2007, Ngo Dang Nghia and Dao Trong Hieu researched drying skinned squid using IRD ceramic drying equipment combined with low temperature air, giving very positive results: drying time of 10-12 hours, clear white color, dries evenly, flat, almost no mold, NH_3 content after drying increases insignificantly compared to before drying [31]. Dao Trong Hieu (2005) researched the application of selective narrow-band IRD ceramic drying technology combined with a heat pump to dry anchovies with shortened drying time (3–5 hours), and final moisture content of products reached 23%. The total number of aerobic microorganisms in the product is $1.1x10^3$CFU/g, protein (61.02%), NH_3 content (12.08 mg/100g). The content of fatty acids is stabled, the fish has beautiful bright colors, straight body, and dries evenly. Compared to the traditional drying method, drying with IRD has a much shorter drying time, so biochemical changes occur less, especially the color and flavor of the product are more preserved, leading to increases commercial value. Furthermore, due to rapid drying and circulating air, hygiene requirements are met, avoiding microbial infection in the air, minimizing the mold growth, and the drying process is carried out at low temperatures. Local overheating that can cause warping or cracking of the product should be avoided [32].

Research by Le Van Hoang (2006) used infrared light bulbs to dry raw beef fillets, white meat tuna, squid, and fresh shrimp. The capacity of each bulb is 250w, distributed in a chessboard position with a height of 300 mm. The drying process is carried out on a conveyor belt with a width of 600mm, and the drying area is $1m^2$ (500 mm x 2000 mm). The results show that to reach a final moisture content of 7%, a floss sample with a thickness of 4mm only takes 1 hour and 15 minutes. The product's color is appreciated, a stabled shape, and non-warp. The radiation method are changed for seafood materials with high humidity for the shorter exposure time and reduce energy consumption [29]. Tran Dai Tien (2007) used IRD drying combined with freeze drying to dry squid skin. The results show: Ink surface temperature 35±1 ^{o}C, wind speed 2±0.1m/s, air humidity 20-40%, air temperature blowing across the ink surface 25±1 ^{o}C, distance from IRD lamp to 40cm ink surface and drying time of 10.2 hours gives the best product quality [33]. Dao Trong Hieu (2012) has determined the appropriate value of the technical parameters in the process of drying anchovies using a selective IRD as: Distance from the source of selective IRD source (ceramic bar) to the source raw (anchovy) is: 10cm; The air temperature in the drying chamber is: 55 ^{o}C and the wind speed passing through the material is: 1.4m/s. The drying time for fish to reach the required moisture content (20±2%) in this mode is 3.5 hours. IRD expressed technological process purpose for drying anchovies to ensure quality, food hygiene, safety, and economic efficiency [34]. Goby fish, squid, shrimp, croaker fish, sea grapes, and snakehead fish have also been applied infrared radiation drying by Hoang Thai Ha and his colleagues to create highly applicable dried products from 2012 to present [35, 36].

4. Conclusion

Synthesis and analysis have shown the causes of quality changes during the drying and preservation of fruits, vegetables, and dried agricultural products composed of fisheries. Infrared drying method uses high heat efficiency, has the ability to kill insects and harmful microorganisms even at low temperatures, this is a superior advantage compared to other heat dryers. Dried products have little change in color, are crispy, not hard, have a delicious natural flavor, satisfy the sensory value of consumers, and the nutritional ingredients are less destroyed. The heat exchange process with the product occurs at high intensity, so the drying time of the product is very fast compared to other drying technologies such as conventional convection drying and solar drying, refrigerated dryers, and dryers. Fluidized bed..., humidity meets requirements, prolongs usage time, while minimizing energy costs, reducing product costs, installation costs are low, suitable for many production scales. The infrared radiation drying method is fit for both plant and animal drying.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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