International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 04 – Issue 05 || May 2019 || PP. 08-14

Studying of Drying of Beef Marinated in Spices by Combining between Heat Pump and Infracted Energy

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Abstract: The paper indicates an experimental method of drying of spicing beef by using heat pump and infrared energy. At the same time, it focuses on researching and evaluating three main technical parameters which influence ondrying time and drying product quality, such as: drying agent temperature, drying agent velocity and distance from infrared radiation source to drying material. Experimental results show that sliced beef thickness from 4 mm to 5 mm, temperature is dried at 320^0C, agent speed is 3.3 m/s, drying relative humidity is 30% and infrared radiation distance is 280 mm will significantly shorten the time of beef drying. In addition, it keep the color of beef dry in light, taste and high nutrient content.
Keywords: Drying method, Heat pump, Compressor, Infracted energy

1. Introduction

Beef is a nutritious material, beneficial for the development of the body and it is trusted by many people. The thickness of fresh beef after washing and slicing is from 4 mm to 5 mm. After that, it is marinated and cooked to ensure hygienic conditions. Finally, cooked beef will be conducted by heat pump compressor combined infrared energy in the optimal drying mode.

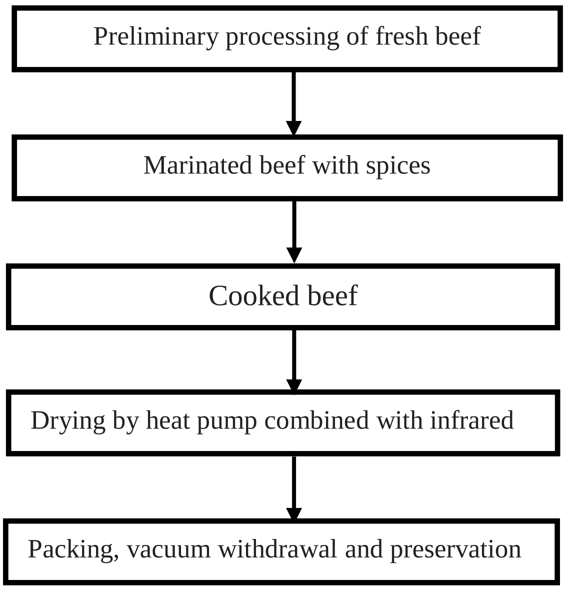

Figure 1: Process of dried beef is marinated

Using experimental method of drying in order to assess the effect of factors on the quality of drying products and drying time of materials. In addition, determining parameters follow:
- The moisture content of the input and during the drying process of beef meat with a moisture measuring device.
- Temperature, relative humidity and drying rate parameters by wind speed measuring device.
- The color of the drying material by a spectrum color analyzer.
- The rate of rehydration of dried cows after drying by soaking dried beef in clean water.

Finally, proceed to weigh until the volume remains constant with the following fomula:

$$A = \frac{G_2 - G_1}{G_1}.100\% \quad (1)$$

A- Recovering water rate (%)
G_1, G_2 - Mass of beef before and after soaking in water, respectively (g)

Figure 2 shows the measuring devices to determine the parameters during the drying process.

Figure 2: Gauges to determine the parameters during the drying process

Assessment of sensory quality (CQ) by scoring method according to Vietnamese standards TCVN T3215-79.
This standard prescribes sensory product quality testing methods, applied to test all sensory indicators or individual criteria (state, taste, blood color and so on) of each the type of product, the test sample is specified as the following Table 1.

Table 1: Range of points to access sensory quality

Quality of products	Range of points to access sensory quality TCVN 3215-79	The average score requirement for each indicator
Broken type	From 0 to 3.9	None
Very poor type	From 4 to 7.1	Each indicator ≥1
Poor type	From 7.2 to 11.1	Each indicator ≥1.8
Medium type	From 11.2 to 15.1	Each indicator ≥2.8
Decent type	From 15.2 to 18.5	The most important indicators ≥ 3.8
Good type	From 18.6 to 20	The most important indicators ≥ 4.8

2. Experimental method

The chamber drying system using heat pump combined with infrared energy is shown in Figure 3, including the following devices:
- The rectangular box-shaped drying chamber is 90cm length, 60cm width, 85cm height, and at the same time there are trays for drying materials. The size of trays to support drying materials is made of 86 cm length and 55 cm width.
- Two fans each with a capacity of 50W. The drying agent speed is adjusted by the number of fan turns through the resistor.
- Cold compressors with a capacity of 145W, two condensers, one internal layout and one external layout, evaporator, automatic valve throttle. The heat pump system is calculated and designed reasonably so that the drying efficiency is of high quality.
- The infrared light bulb may adjust the radiation distance to the surface of the drying material. The temperature of the drying agent (due to the exothermic process of the refrigerant from the condenser and infrared radiation) is surveyed in the range of 20^oC to 40^oC. When the temperature of the drying chamber is satisfactory, the temperature regulator will disconnect the power and the compressor stops operating [4].

- Sensors for temperature, humidity, drying rate and refrigerant pressure are placed in a reasonable position to ensure the highest accuracy. Other parameters are considered optimized.

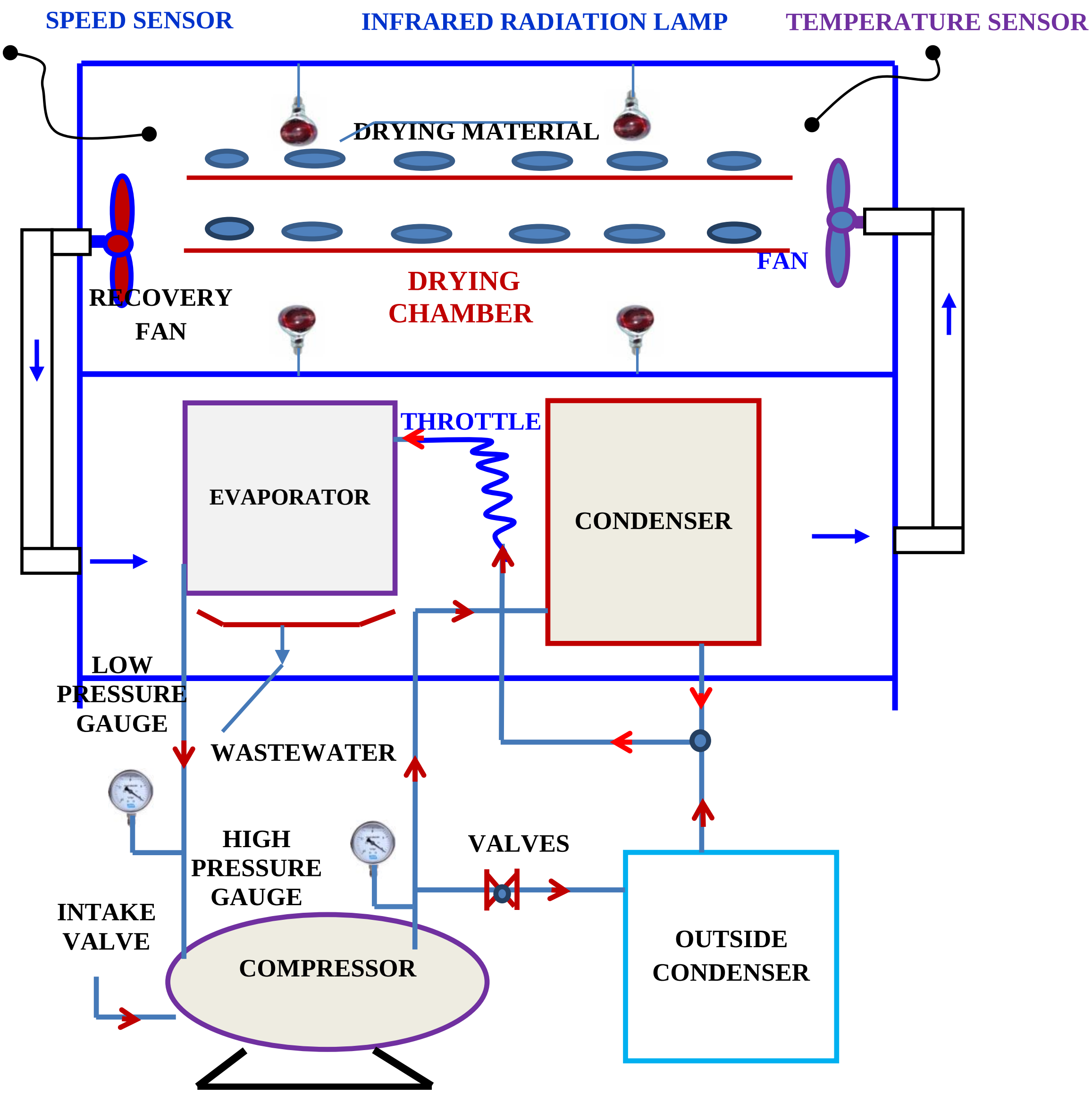

Figure 3: Diagram of the principle of drying system

The drying agent (DA) is a moist air, first of all, through the evaporator cooled and dehumidified, a quantity of moisture is extracted in the form of condensate, then DA becomes drier and passes through the condenser. Here, DA is heated by the refrigerant emitted and increases the temperature and reduces the relative humidity. Then DA enters the heat and moisture exchange drying chamber with the drying material (DM), the moisture of DM escapes mainly due to the differential pressure difference between DA and DM, this moisture will be brought to the evaporator, moisture by DA. Once again, the cycle continues.

During the drying process, a large number of parameters affect the working efficiency of heat pump [1,6,7] and product quality after drying such as: characteristics of drying material, temperature, humidity, drying regime and so on. Nevertheless, in the content of the article, only focusing on researching and evaluating three main technical parameters with great influence are: Drying agent temperature, drying agent velocity in drying chamber and distance from infrared radiation source to DA surface. The product after drying was evaluated sensory quality by scoring method according to Vietnam standard TCVN 3215-79. When conducting empirical research, in order for the evaluation to take place smoothly and provide results accurately, some elements are prepared such as: time, place, material, human and the content of the evaluation method.

The experimental drying model is shown in Figure 4.

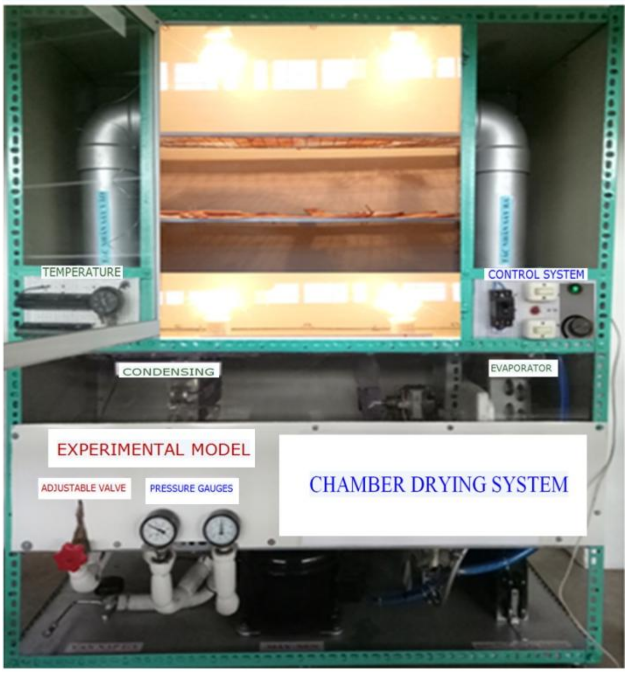

Figure 4: The experimental drying model

3. Results and Discussions

Drying materials are sliced spiced beef from 4mm to 5mm thickness, input moisture content of 70% arranged on trays to ensure a suitable density, good moisture removal process, meanwhile the output moisture after drying is 25%. During the drying process, it is necessary to regularly use DA island to dry evenly. Based on the measurement data many times, results are analyzed.

Figure 5: Sliced spiced beef before and after drying

3.1 Effect of drying agent temperature on drying time and sensory quality score

During beef drying, the amount of water changes in DA depends on the state parameters of the DM. The higher the DM temperature, the faster the amount of water in the detached material, shortening the drying time. Nevertheless, when the drying temperature is too high, it will affect the product quality and easily cause stiffness in the outer layer, hindering the movement of water from the inside out. In contrast, if drying is too low (no heat pump is used) due to the high humidity of the air environment, moisture drainage will slow down, leading to rotting, reducing product quality. Therefore, during the experiment on the dryer using heat pump combining infrared energy, the temperature range selected from 20^{o}C to 40^{o}C is in accordance with the above criteria.

The change of sensory quality score of beef shown in Figure 6 shows that at the same rate of drying agent is 3.3m / s; when the drying temperature is increased to 32^{o}C, the highest quality of CQ is achieved. Meanwhile, at temperatures of 20^{o}C or 40^{o}C, the sensory quality is smaller.

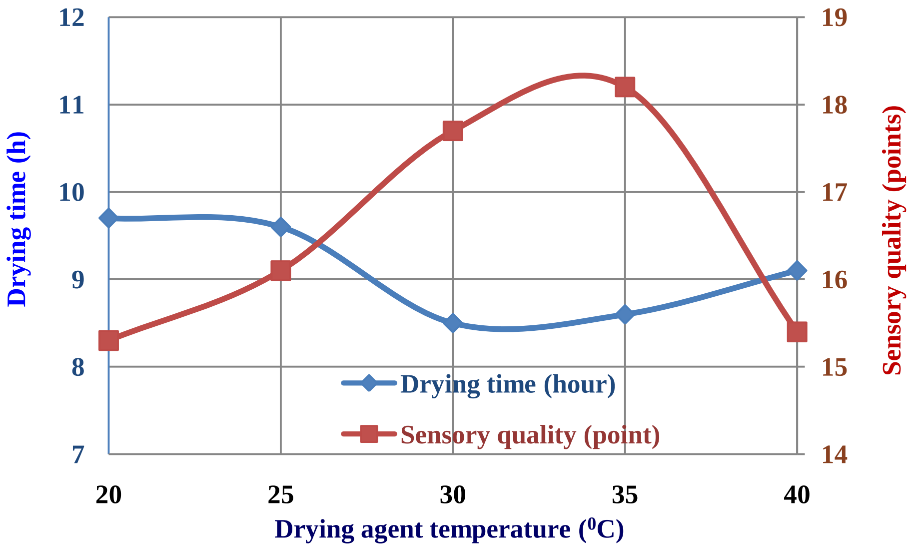

Figure 6: Change of drying time and sensory quality score according to drying agent temperature

When drying at 20°C, the foreign diffusion process slows down the drying time, facilitates the enzymatic activity of protein hydrolysis and the oxidation of minerals [2,5] reduce product quality. In contrast, when drying at a high temperature of 40°C, the external diffusion process disrupts the balance between foreign diffusion and internal diffusion. This causes the surface of the meat to be more prone to film formation, overheating, and enhanced color-changing reactions. Therefore, the color and flavor of beef after drying reduced to 15.4 points. From the above experimental results, when drying beef, it is recommended to select the optimal temperature range from 30°C to 35°C, allowing the drying product to be uniform in color and quality and shortening drying time.

3.2 Effect of drying agent speed on drying time and sensory quality score

The speed of the drying agent has a direct effect on the drying of the material. If you choose too high a speed, it will take a large range of thermal energy to keep the temperature needed on the surface of the material. Conversely, when the speed is too small, the drying process will slow down, leading to a decrease in product quality. In this experiment, select the drying agent rate from 1m/s to 5 m/s and the results are shown in Figure 7.

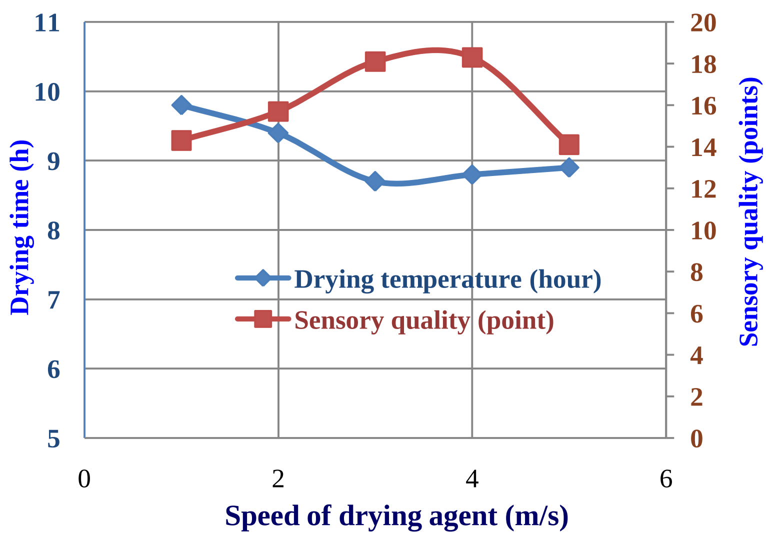

Figure 7: The change in drying time and CQ point according to the speed of drying agent

When drying at the same temperature of 32°C, the drying agent velocity from 2.9 m/s to 3.5 m/s shows the change in the moisture content of the drying material uniformly, the highest quality of the CQ, while the drying speed is 1 m/s or 5 m/s the change in the humidity of the market is too fast, the time is too slow to make the CQ score low. This is explained that when drying at small velocities of 1 m/s, the evaporation coefficient is small, so the drying speed is slow and the drying time lasts nearly 10 hours. In contrast, when drying at a high speed of 5 m/s, it is difficult to keep the heat on the material to balance the drying process. On the other hand, since the evaporation coefficient is too enormous, the greater the diffusion rate of the internal diffusion, making the surface of the beef has stiffness, hampers the diffusion process and prolongs the drying time. Therefore, it is recommended to choose the optimal velocity range from 2.9 m/s to 3.5 m/s, which will give the best quality and yield.

3.3 Effect of radiation distance on drying time and sensory quality point

The experimental results in Figure 8 show that, at the same temperature 32°C; wind speed 3.3 m/s dried beef at radiation distance from 250 mm to 300mm gives the highest quality of CQ score, while at the radiation distance less than 150 mm, the quality of CQ is low. Because at this distance near infrared lights, the radiation source is large and distributed on the surface of the beef unevenly, making the surface too hard but having a moist place and high temperature causing the product to overheat, resulting in hardening of the surface; color and quality are reduced, so CQ only achieves from 14.5 to 15.7 points and prolongs drying timefrom 9 hour to 10 hour.

At a radiation distance of 350 mm, due to the distance from the infrared light, the product surface receives little infrared radiation, although the product is not dry and cracked, the color is better, but the drying time is longer than 9hour, creating conditions for microorganisms to work to reduce product quality, so the quality of CQ only reaches 15.8 points. From the above analysis results, optimal infrared radiation distance from 250 mm to 300mm for good dry market quality and better color.

After designing and arranging experiments [4] according to the experimental planning method, optimizing technology conditions by the least squared method, processing experimental results. The results of the best drying regime for the spice-drying beef by heat pump combined with infrared energy are: drying temperature of 32°C, agent speed 3.3 m/s; 280 mm radiation distance. This result reflects closely the experimental research process.

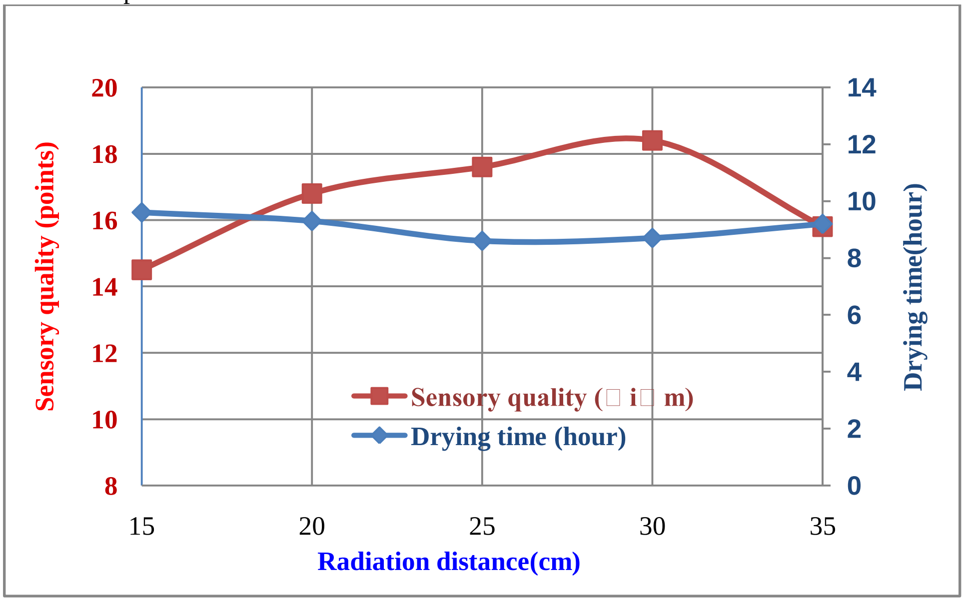

Figure 8: The change in drying time and CQ according to radiation distance

4. Conclusion

When drying spice marinated beef by compressor heat pump combined with infrared radiation, during the drying process, the moisture content of drying material (DM) still tends to decrease gradually. This is different from other conventional drying methods, showing that cows do not suffer from surface bottles. The reason is that the internal diffusion and foreign diffusion process of moisture in DM still occurs regularly and easily, this is the most outstanding advantage of this method.

The results of the evaluation of the targets of dried beef and sun-dried beef are reflected in the recovery rate of rehydration which is 52.5% of the mechanical drying market is much higher than that of natural sun drying. Due to the shorter drying time compared to sun drying, the activity of intrinsic microorganisms and enzymes should be limited to reduce hydrolysis, mineral oxidation and coloration reactions. The reason for this difference is due to differences in the amount of moisture released from the VLS surface. The amount of moisture evaporated from the surface of the DM is directly proportional to the evaporation coefficient, the difference in steam pressure on the DM surface with the partial pressure of water vapor in the humid air. The partial pressure of mechanical drying samples and natural sun exposure samples are nearly the same, only different from the evaporation coefficient [1,7]. The evaporation coefficient is directly proportional to the wind speed moving through the surface of the material. With sun drying samples due to natural wind velocity as natural convection and actual results average from 0.5 m/s to 1 m/s, the amount of moisture evaporates very slowly. While the drying sample has a speed of blowing through the surface, it is usually from 2.9 m/s to 3.5 m/s, so the evaporation coefficient is much higher. Therefore, the average drying speed of these two methods is quite large. On the other hand, due to the bactericidal infrared rays, the low biochemical changes of DM rarely occur. The low drying temperature causes the product to avoid local overheating to keep the color well.

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