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Heat Pump Technologies for Drying Agricultural Productsand Medicinal Herbs: A Review

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ABSTRACT: Drying agricultural products and medicinal herbs is a process that consumes a lot of energy. The conventional hot air drying technique is most widely used for grain agricultural products, dried fruits, medicinal herbs, etc., often leading to product loss of nutrients, vitamins or other nutrients. pharmacological characteristics. To address this drawback, drying technologies have been researched in recent years.Heat pump (HP) technology canadjust the temperature, humidity and drying process of the drying agent. This paper reviews heat pump (HP) technologies for drying agricultural products and medicinal herbs.

KEYWORDS:drying agricultural products, heat pump, solar energy, saving energy.

I. INTRODUCTION

According to the report of the World Food Organization (FAO) in 2020, worldwide today, annual post-harvest food loss is about 1.3 billion tons, of which this proportion is for Developing countries account for about 30-40% of total food production, losses are mainly in post-harvest and processing stages [1,2]. For developed countries, this value is mainly at the consumption stage (retail) and the consumer side [3,4]. According to statistics, in some developing countries, the post-harvest loss rate for vegetables and fruits is about 25%, and medicinal herbs have a mold rate of 12-28% during storage. Therefore, the issue of post-harvest preservation of agricultural products and medicinal materials is a matter of concern for many countries.

For temperature-sensitive agricultural products, fruits, and medicinal herbs, drying technology under environmental humidity conditions often causes phenomena such as long drying times and product color changes. Vitamin content or medicinal properties are not preserved. In developed countries like Japan, Korea, Australia or Thailand, fruits such as mango, apple, jackfruit, custard apple, durian... are often used freeze drying technology or vacuum sublimation drying technology to preserve color as well as nutritional value of the product. Especially for fruits such as soursop, in addition to its rich vitamin content, it also has pharmacological properties such as the leaves of the soursop plant have a light fragrance thanks to the presence of essential oils, which have a mild calming effect, reducing the risk of stress. respiratory excitement. The fruit contains carotenoids: lycopene, lutein, Tocopherol α, Cryptoxanthin β, antioxidant activity. It also contains a lot of glucose and vitamin C. The above active ingredients all have antioxidant properties that prevent the development of cardiovascular diseases, cancer, arthritis, Parkinson's, and Alzheimer's. From dried fruit, water extract: acetone [1:1] selectively inhibits the growth of breast cancer cells with IC50 value = 4.8 µg/ml.

Due to seasonal characteristics, agricultural products and medicinal herbs need to be dried and preserved to ensure that the production and supply of products is continuous and uninterrupted. However, drying agricultural products and medicinal herbs is a process that consumes a lot of energy. The conventional hot air drying technique is most widely used for grain agricultural products, dried fruits, medicinal herbs, etc., often leading to product loss of nutrients, vitamins or other nutrients. pharmacological characteristics. To address this drawback, drying technologies have been researched in recent years [5]. One of these technologies is the use of heat pump (HP) technology, which allows the temperature, humidity and drying process of the drying agent to be adjusted [6].

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This paper reviews heat pump (HP) technologies for drying agricultural products and medicinal herbs.

II. OPERATING PRINCIPLE OF HEAT PUMP SYSTEM

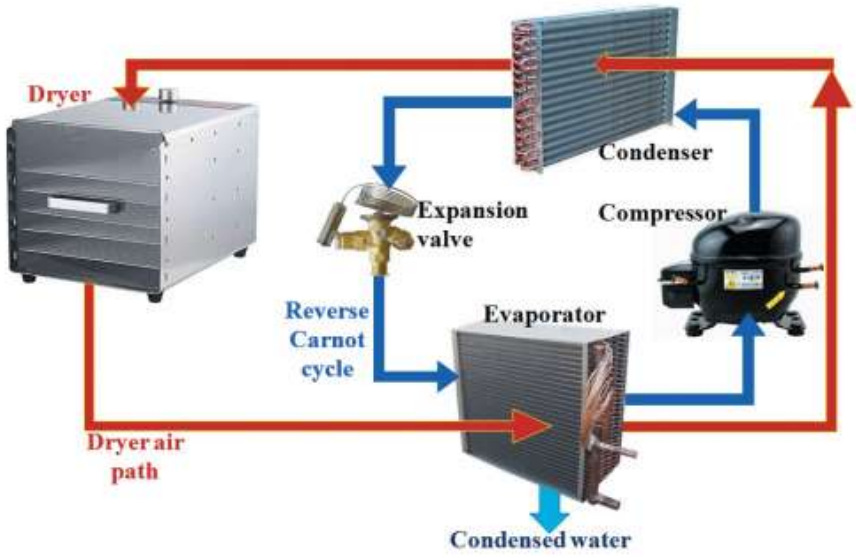

Figure 1. Principle diagram of the drying system using heat pump [7]

HP dryers are increasingly widely used in the agricultural product preservation industry as well as the food and pharmaceutical industries due to low energy consumption and improved product quality due to nutritional value. the product's mass value to its sensory value. The energy saving of HP dryer is based on the principle of reverse Carnot cycle (refrigeration cycle), it can utilize energy from exhaust gas and independently control the temperature and humidity of the air [8].

Figure 1 shows the principle diagram of the HP drying system (reverse Carnot cycle) including two heat exchangers (evaporator and condenser), expansion valve and compressor; Integrated with drying chamber. Therefore, the HP dryer is made up of 5 main parts including compressor, condenser, evaporator, expansion valve and drying chamber.

+ Operating principle:

- Airpath: Air under environmental conditions, after passing through the condenser, is dehumidified to form dry air (relative humidity of the air decreases) and then exchanges heat with the refrigerant at the condenser. elevation from 30^0C up to 50 - 60^0C and fed into the drying chamber. Here, the air has high temperature (50 - 60^0C) and low humidity, exchanging heat with the drying material, evaporating the water in the material.

- Path of the refrigerant: The refrigerant performs a closed circulation process in the refrigeration system including the compressor sucks refrigerant vapor from the evaporator and performs an adiabatic compression process that changes the state of the refrigerant (temperature). high, high pressure) and pushed into the condenser. At the condenser, the refrigerant exchanges heat with the air to reduce temperature and pressure, then performs the throttling process and circulates back to the condenser to complete a closed cycle.

Thus, the driving force of the drying process is the physical parameters of the drying agent when put into the drying chamber (the temperature difference of the air at the time the air leaves the condenser and the air leaves the evaporator is Δt = 16-25^0C, the air entering the drying chamber now has the following parameters (humidity <30%; temperature from 36-500C)), with the air state as above, when in contact with moist materials The rate of water evaporation in the material is more intense and is carried out at low temperatures, thus limiting surface gelatinization for agricultural products with glucose content or little effect on the physical structure of the material. cells, in order to preserve the nutritional value as well as the pharmacological properties of the materials to be dried.

HP dryer application is suitable for high-value, temperature-sensitive products, medicinal herbs... because it has the ability to control conditions of temperature, humidity and air velocity, thus increasing improve product quality and reduce drying costs[9].

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Some researchers have compared the performance of HP dryers with other dryers and found that HP dryers consume 60–80% less energy than conventional dryers operating at the same temperature [10]. For example, drying sliced onions with an HP dryer consumes less energy than with a conventional hot air dryer and has better sensory quality [11].

III. HEAT PUMPTECHNOLOGIES FOR DRYING AGRICULTURAL PRODUCTS AND MEDICINAL HERBS

Because the need to use energy for drying agricultural products is very large, although HP drying technology has been found to bring high efficiency and good product quality. However, research needs to focus on hybrid HP dryers with renewable energy sources to reduce electrical energy consumption while still ensuring product quality criteria. Therefore, the research on combining renewable energy sources with HP dryers aims to make the drying process faster, not only the water evaporation rate but also the drying time is shortened while still ensuring product quality factors (ensuring moisture as well as nutritional value), equipment performance and energy saving. Currently, heat pump dryers are often combined with other forms of energy such as: using infrared radiation, using solar radiation energy, biomass energy or combined with a sublimation vacuum system... As follows:

+ HP drying system combined with solar radiation energy

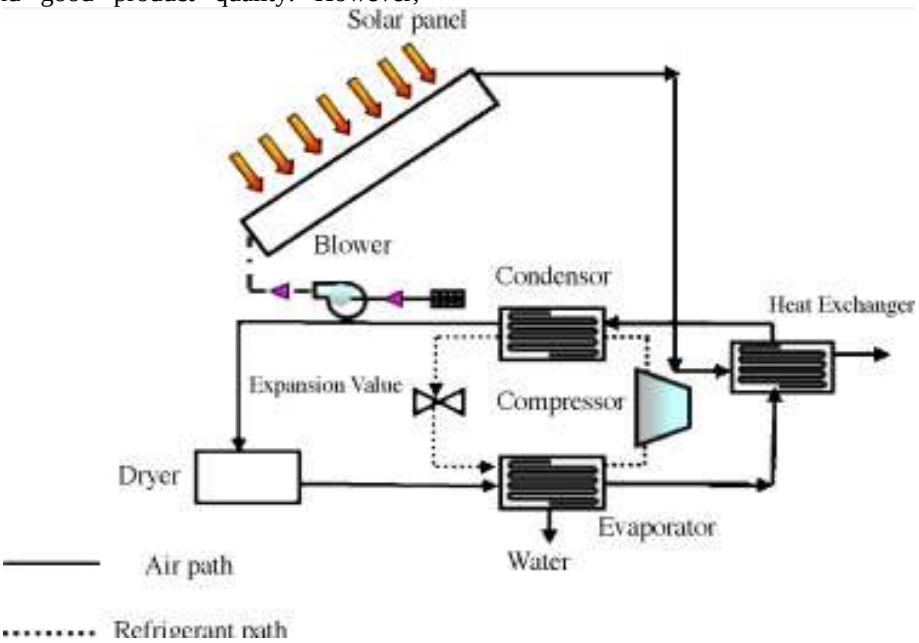

Figure 2. HP drying system combined with solar energy

The HP dryer system combined with solar energy was designed and used to dry sliced bananas, the results obtained were compared with the HP dryer using R134a refrigerant as follows [12]:

+ Average drying speed: HP dryer (0.205 kg/kg min) is smaller than HP dryer combined with solar energy (0.342 kg/kg min);

+ The performance of the HP dryer is smaller than the HP dryer combined with solar energy.

In another study where banana drying was experimentally used [13], it was demonstrated that the HP dryer reduced the initial moisture content of bananas from 74% to a final moisture content of 19% in 21 hours. Similarly, the HP dryer combined with solar energy reduces initial moisture from about 74% to final moisture of about 19% in just 15 hours.

HP drying system combined with infrared radiation energy

Performance analysis of HP and infrared drying in drying carrot fibers [14] published the following results:

+ Energy efficiency in this study ranges from 50% to over 80%; HP dryers with infrared ray support save 48.8% drying time compared to HP dryers.

+ The maximum efficiency of the device is 66.8% while the minimum efficiency of the device is 31.6%.

+ This study shows the successful and

effective combination of HP and infrared in food drying.

HP drying system combined with sublimation vacuum system

Vacuum drying is a method of drying food products with a high drying rate because the vapor pressure of the air in the product is lower than the pressure of atmospheric air (lower temperature drying) and water vapor is removed by a vacuum pump. In this method, the contact between the dried material and oxygen is limited [15]. In recent years, vacuum HP drying has been researched as a potential method to obtain high-quality products, especially for use in drying raw materials in the pharmaceutical and cosmetic industries. This drying technique combines the advantages of both HP drying and vacuum drying. However, this type of drying equipment has quite a large cost, so it is suitable for pharmaceutical or cosmetic production models that require deep processing with high added value and are feasible in terms of economic efficiency. When drying ingredients that contain high amounts of vitamins and are sensitive to temperature such as shiitake mushrooms and Jinda peppers, they were studied under different conditions of drying temperature (50–65^{0}C) and vacuum pressure (0, 1-0.4 bar) in a vacuum HP dryer. The results show that drying temperature and pressure significantly affect the color change. Additionally, the rehydration capacity of drysamples decreased significantly with increasing vacuum pressure [16].

Thus, HP drying technology and other forms of energy show that the HP drying system combined with renewable energy sources [17,18] has outstanding features such as energy costs used to evaporate 1kg of water. decreased compared to other drying methods, the COP coefficient increased; The effective moisture diffusion value is within the allowable range. Therefore, the HP drying system combined with renewable energy sources has been developed in both quantity and equipment capacity. However, the hybridization of HP dryers with renewable energy is mostly simply done in the form of hybridizing two objects, i.e. between HP and solar energy or between HP and biomass. The seamless combination of HP, solar energy and biomass objects has been initially implemented in some places, but the number of studies and practical applications is not much. Therefore, research on drying systems using HP, solar energy and biomass energy sources needs to be researched and developed more widely and popularly in the world to serve the needs of processing and preserving agricultural products and fruits. plants, medicinal herbs... to reduce post-harvest losses, save energy and improve product quality.

IV. CONCLUSION

HP drying system combined with renewable energy sources has been developed in both quantity and equipment capacity. However, the hybridization of HP dryers with renewable energy is mostly simply done in the form of hybridizing two objects, i.e. between HP and solar energy or between HP and biomass. The seamless combination of HP, solar energy and biomass objects has been initially implemented in some places, but the number of studies and practical applications is not much. Therefore, drying systems using HP, solar energy and biomass energy sources need to be researched and developed more widely and popularly in the world to serve the needs of processing and preserving agricultural products and fruits. plants, medicinal herbs... to reduce post-harvest losses, save energy and improve product quality.

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