

Study of the Solar Energy Drying Device and Its Application in Traditional Chinese Medicine in Drying

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Abstract

Background: We referred to nearly 40 years of development and application progress of solar dryer in China literature, especially its application in the field of Chinese herbal medicine drying. **Objective:** We explored the development direction of China's development and application of solar dryers, especially focusing on its development and application in traditional Chinese medicine drying. **Method:** Five types of solar dryers including the greenhouse type solar dryer, the collector type solar dryer, the collector-greenhouse type hybrid solar dryer, the integrated solar dryer and the focusing type solar dryer accounted for the development and application of solar dryers up to 95% in China. The first three types of solar dryers are low temperature dryer (less than or equal to 70°C), while the latter two kinds of solar dryers are high temperature dryer (more than 70°C). In this paper, we respectively introduced and compared the structure, working principle, applications, advantages and disadvantages, and the research status of these five dryer. **Results:** The integrated solar dryer and the focusing type solar dryer belong to the high temperature dryer types are the future direction of development. Among them, the integrated solar dryer is relatively simple structure and has more promotion prospects. These two kinds of key drying device used in the dryer is the development direction of high efficient vacuum tube. On the other hand, because of their low cost, simple structure and the dry material requirements etc., the three types of low temperature dryers at low temperature for drying materials are also indispensable in the practical application. In contrast, the collector-greenhouse type hybrid solar dryer has more advantages, is the development direction of low temperature drying category. **Conclusion:** The collector tube which is the key element of the dryer was the core technology of solar dryer. Our country develops more successful of the all-glass vacuum solar thermal collectors and heat pipe-glass vacuum tube. Efficient vacuum tube collector technology is the future developed direction and is equally important to improve the quality of traditional Chinese medicine and dried.

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Keywords

The Solar Energy Drying Device, Vacuum Tube Collector, Traditional Chinese Medicine Drying

1. Introduction

Solar energy as a green energy is a clean, cheap and renewable energy. With the gradual warming of global climate and global not renewable energy decreased year by year, it is expected the solar energy will play an even more important role in social production and life in 21st Century. China is located in the northern hemisphere in the eastern part of Eurasia, with abundant solar energy resources. The average annual sunshine hours over 2600 hours and 2/3 over the land annual radiation total more than 6×10^6 kJ/m² [1]. In the field of traditional Chinese medicine production, using the oven or steam dryer instead of the traditional drying process to dry traditional Chinese medicinal materials and certain forms such as pills which could meet the production concentration and large processing capacity requirements. But there are shortcomings, such as the uneven distribution of temperature, fast heating rate, the temperature drying that is not easy to control and this drying method that is not suitable for containing volatile components of drugs, lower thermal efficiency, high energy consumption, poor economic benefit. Solar installation drying certain traditional Chinese medicinal materials, Chinese medicine decoction piece and Chinese patent medicine could keep the original components and color, flavor, good appearance quality, and quality assurance. In recent years, along with the whole glass vacuum tube solar collector and heat pipe-glass vacuum tube technology coming out, which greatly promoted the development of solar heat utilization, and widely used in the field of solar energy water heater. Relatively speaking, the research on application of solar drying has started later and the research is relative lag, especially in the application of traditional Chinese medicine is the study of the drying less. Many varieties can be used the solar drying device, such as traditional Chinese medicinal materials, Chinese medicine decoction piece, Chinese patent medicine, arts and crafts pottery, preserved fruit, vegetables, meat, fish, grains and wood, etc. We will now proceed to a brief presentation on the status of their application and research in Chinese medicine, and discuss its future development prospects.

2. Types and Characteristics of the Solar Energy Drying Device

There are multiple types of solar energy drying device. According to the material receiving solar energy, the solar energy drying device can be divided into two categories: direct and indirect heating, otherwise known as radiant and convection. Our country customarily called them greenhouse type and collector type solar energy drying device (as shown in **Figure 1** and **Figure 2**). They combine with greenhouse collector type dryer which was called hybrid dryer (as shown in **Figure 3**). According to the different dynamic air flow, the solar energy drying device can be divided into active and passive two categories. The general greenhouse type dryer is passive, while the collector with a dryer, especially the larger, is more active. In addition, there are integral parabolic concentrator dryer, far-infrared dryer, vibration fluidized bed dryer, etc. Sometimes in order to materials on continuous drying, the collector type solar dryer can also be provided with a combustion furnace, using wood or coal as an auxiliary energy solar energy (as shown in **Figure 4**). The heat collector of solar greenhouse dryer which equipped with steam heat conduct joint heating could meet the 24-hour continuous production. Even the integrated solar dryer and small hydropower combined can multi complement each other, in order to operate all the day. It could save energy and electricity if the large-scale solar drying device combines with conventional energy sources and with the high degree of automation, the industrial control computer operation and monitoring are adopted.

In these dryers, four types including domestic greenhouse type, collector type, the collector-greenhouse type hybrid solar dryer and the integrated solar dryer accounted for more than 95% of the applications have been developed solar dryer [2]. Among them, the greenhouse type, collector type, collector-and the overall greenhouse-type solar dryer mainly belong to the low temperature dryer which the drying temperature is below 70°C. The drying operation and its application range including traditional Chinese medicinal materials, Chinese medicine decoction piece, Chinese patent medicine, wood, leather, grain, fruit, tobacco, meat etc.

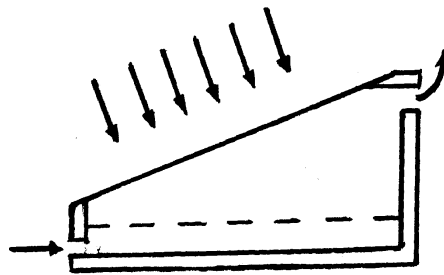


Figure 1. Hothouse model.

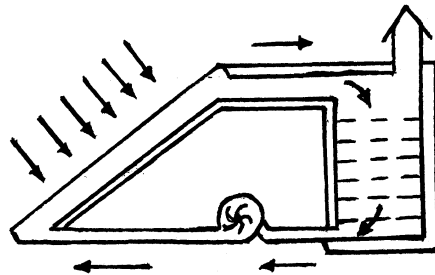


Figure 2. Convection cycle model.

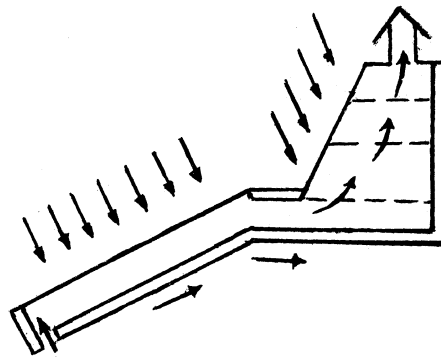


Figure 3. Mixed model.

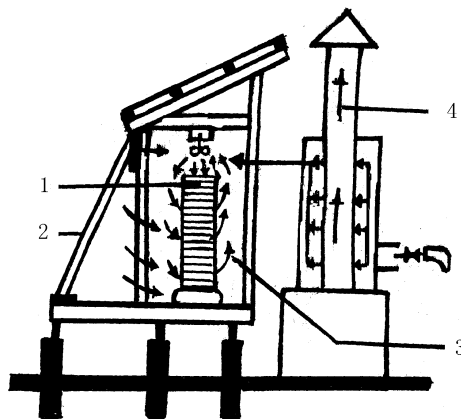


Figure 4. Diagram of the solar energy drying device taking waste wood (coal fuels) as additional energy resources. 1-materials for preparing to dry; 2-heat collector; 3-drying house; 4-hot-blast stove burning through waste wood (coal fuels).

2.1. The Greenhouse Type Solar Dryer

This dryer actually has a solar greenhouse humidity discharging capacity, whose heat collecting part and the drying chamber are combined into a whole. The north wall of the dryer is usually insulated walls and painted black, at the same time have heat absorption and heat insulation effect. The half of south, east and west are insulated walls, and half above are pervious to light glass walls. Greenhouse floor is black.

The top of the dryer is a large area of southward tilt glass cover, while the south wall on the ground is arranged on the bottom of a certain number of vents. There is exhaust chimney at the top of the greenhouse which near the north wall of the site in order to form a natural convection circulation pathway. During the operation, we could control temperature and humidity inside the greenhouse through the installation of the exhaust chimney in the damper [1]. The model is shown in **Figure 5**.

The solar energy drying device of hothouse which efficiency is very low receive the solar total radiation energy effective utilization rate is only 15% used for moisture evaporation materials, mostly lost to the atmosphere. This solar energy drying device can be designed as a solar dryer. The American scholar Peter Y. S. Chen and Charies E. Helton designed solar dryer with a heat storage device as an example [3] (as shown in **Figure 6**). The appearance of the dryer is similar to a right triangle. The south wall (top) is tilted 7.5° which inclined at the same latitude. The dryer is composed of four parts: material drying room, solar collector, thermal storage device and the collector plate reflector. The drying chamber wall and ceiling material is glass fiber board and polyurethane resin plate (total thermal insulation = $20 \text{ m}^2 \cdot \text{K/W}$). The ground insulation use glass fiber board, plywood, polystyrene foam and concrete layer (total thermal insulation = $20 \text{ m}^2 \cdot \text{K/W}$). There is a dust with a glass fiber board wood frame between the dry material and concrete pile. The outer surface of the drying chamber is covered with plywood. The collector is made of double-layer glass plate which was spaced apart with glass fiber. Accumulation of thermal storage devices are paved with concrete blocks which are stacked into a right triangle with the same tilt as the south wall (top). The inclined surface is painted black whose effect is the absorption of solar radiation and the drying chamber exchanging heat with the circulating air. The collector plate reflector is made of plywood and polyurethane resin plate with aluminum foil on the surface.

During the sunny day, the cover plate reflector has reflected solar radiation effect; while on a rainy day and night, the cover plate reflector acts as a reflector to prevent losing heat through the glass plate to maintain the room temperature.

Greenhouse type drying system has the advantages of simple structure, low cost, suitable for basic unit to use. This dryer is suitable for the requirements of drying temperature is low and allows direct exposure to the sun's material. When the drying temperature below 60°C , greenhouse type drying system is more commonly used,

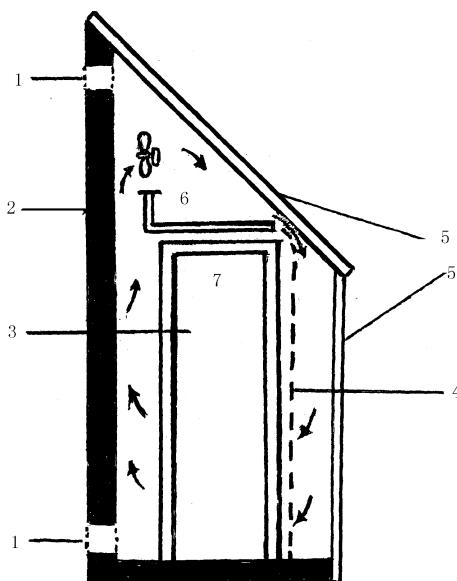


Figure 5. Diagram of the solar energy drying device of hothouse model. 1-ventilation hole; 2-north wall; 3-entering door; 4-mesh screen; 5-double glass; 6-fan stage; 7-drying house.

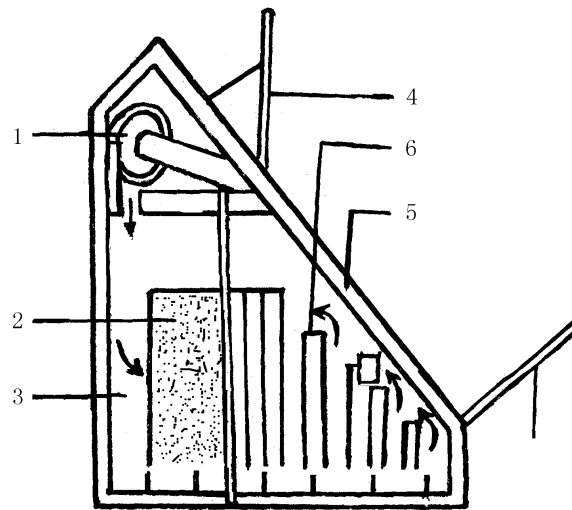


Figure 6. Diagram of the solar energy drying device with stoving heat. 1-air machine; 2-materials; 3-drying house; 4-covering board of heat collector reflector; 5-solar energy heat collector; 6-device with stoving heat.

such as Chinese herbal medicine in flower, leaf, red jujube which could be basked by the light of the sun. Compared with the natural stand in the sun, the drying time of this drying device can be shorted 60% to 70% [1].

In the domestic, the study of this type drier in traditional Chinese medicine drying includes simple box type solar cooker and simple activities of solar drying room. The experimental results show that: the traditional Chinese medicinal materials drying effect of box type solar cooker is better than the constant temperature box and natural sunlight [4]. In Shanxi province Jishan County Yao Cun and Datong etc., people had started to use the solar dryer for drying jujube and other products since 1977. Practice shows that the dried jujube decay rate from the past natural drying method of 16% - 20%, drop to 2% - 3%. Meanwhile, the jujube with beautiful plump, bright red color, taste good which improves the product grade [2] [5]. 158 m² greenhouse type solar dryer was developed thermal Engineering of Tianjin University for Beijing Tong Ren Tang Herbal plant factory, and was used for drying production of Chinese herbal medicine. With the new triangle double transparent cover plate, automatic chain transmission mechanism and complementary solar energy and steam equipment, the drying effect of this dryer is 0.22% - 0.3%. By working 18 hours a day, the annual solar guarantee rate is 20% [5].

2.2. Collector Type Solar Dryer

This dryer is equipped with the collector. The materials to be dried are not directly affected by sunlight, but placed in a dry indoor. The air is heated by the fan to the drying chamber, and generate convective heat transfer between the material being dry, in order to achieve the purpose of drying. Its general structure is shown in **Figure 7**.

Here they mostly use specially designed air collector for air heating. General water heater also can be used for air heating, with which the water is heated and the heat air through the heat exchanger. In order to make the dryer can run continuously, the dryer is usually equipped with simple heat storage device and radial heating system.

The exhaust pipe is provided at the top of the dryer, through the control valve to the atmosphere.

This valve with an air collector blower of the air collector can control the flow, temperature and humidity in the wind according to the needs of material drying process [1].

This dryer has the following advantages: 1) can adjust the temperature of the hot air drying according to the material characteristics; 2) can accommodate more material per unit area, because the material in a dry indoor layer; 3) strength the convective heat transfer so that the drying effect is better; 4) the dryer to heat the air to 60°C - 70°C, which is suitable for the drugs that could not dry by the sun direct insolate, such as deer antler and slice of astragalus, etc. [2].

Now the development of mature air collector basically can be divided into three categories: non-permeable, permeable and aggregated category. Non-permeable air collector with the problems that the top layer of air

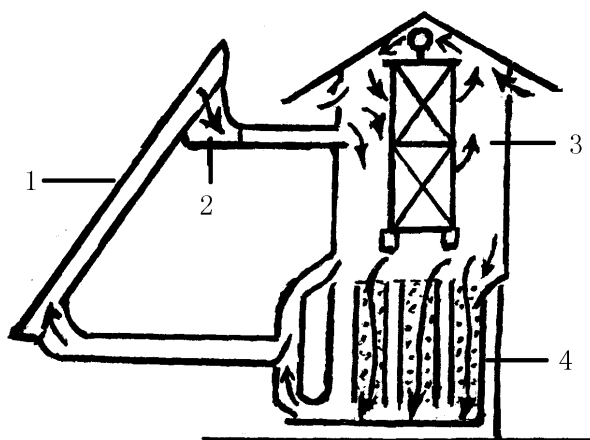


Figure 7. Diagram of the solar energy drying device of heat collector model. 1-solar energy air heat collector; 2-air machine; 3-drying house; 4-trough for stoving heat.

convection heat absorbing plate or radiant heat loss are more difficult to solve. In addition, increasing the maximum heat exchange area in the per unit area of the collector that is more difficult to achieve. Therefore, this type of collector is not ideal. The air heat transfer area of the permeable air collector in the unit area collectors is larger than non-permeable. With less slope top heat loss, the permeation type air collector is easy to form temperature field distribution with the upper low temperature and the lower high temperature. Among them, the porous layer of the absorber plate of the honeycomb structure has a special significance to prevent vertical convection heat loss and air vortex. Due to the complex structure, excessive material consumption and complex process, most of the honeycomb structures are less likely to choose and the large area promotion is limited by conditions. Condenser type dryer is the sun with a curved mirror to focus poly together to form a high-temperature region where the material to be dried quickly after entering the enclave height dry. Condenser type dryer which makes the air collector and drying chamber into one has complex device structure. This type dryer is special used for directional sun tracking system and average material transmission mechanism. Except for special use, this system is rarely used and also does not have the possibility of widespread popularization and application [6] as shown in **Figures 8-10**.

Comprehensive technical and economic performance analysis: because of the smaller volume and less capacity, small solar dryer is used in basic unit and all aspects of performance requirements are higher. Speaking from the system, the hybrid solar dryer is more ideal. Considered from the collector structure, honeycomb structure of solar dryer efficiency is higher. Actually, after cutting off the upper and lower end, pressuring to form a square, rectangular, or after prismatic hexagon, the alumina hollow cylinder cans which are neatly arranged around a heat insulation air collector could be made into a kind of honeycomb structure, high-performance solar air collector. Experiments show that, this kind of honeycomb structure infiltration air collector has the characteristics of light structure, low cost, simple process, higher thermal efficiency. This kind air collector which belongs to a new generation of solar air collector could effectively formation temperature field distribution, with excellent technical and economic performance to prevent the vertical heat convection.

In the domestic area of Traditional Chinese medicine drying, the Tianshui branch pieces factory of the Gansu Pharmaceutical general corporation built a convection solar drying apparatus for drying pieces in 1987 [1]. The first Shanghai Chinese medicine pharmaceutical factory cooperated with the Shanghai Energy Research Institute to develop a set of simulated solar collector drying apparatus for drying medicine pills. This device was composed of air heater, fan room, with air filter air box, drying box components, etc. (as shown in **Figure 11**). Simulation device for drying medicine has three modes of operation: 1) internal circulation; 2) outside the circle; 3) row of wet cycle. The experimental data show that: all the indicators of the device are superior to the conventional oven to dry pills [7]. During the period of “seven five”, Tianjin university built the first relatively complete drying characteristics of material test device in our country. The device could be used to simulate the operating conditions of solar air collector type drying apparatus. We conducted a pilot study on drying characteristics of traditional Chinese medicine such as ginger, lentinus edodes, evening primrose oil, ginseng, gastro-

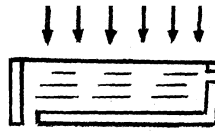


Figure 8. Osmotic model.

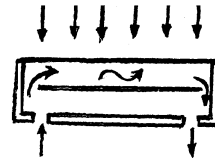


Figure 9. Nonosmotic model.

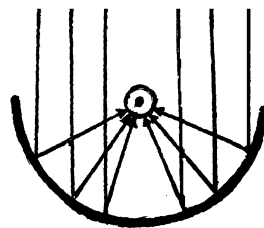


Figure 10. Heat collector model.

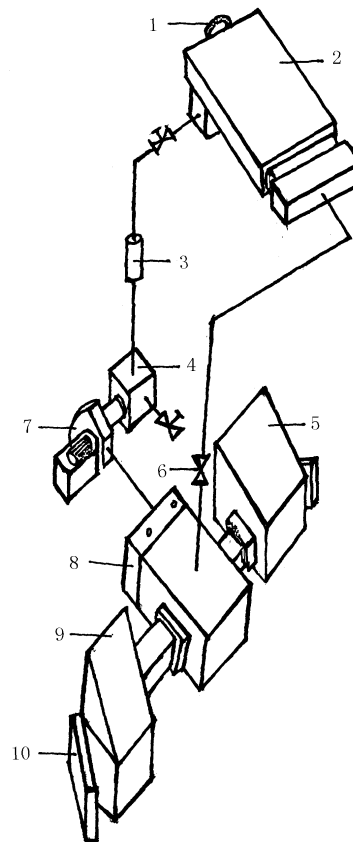


Figure 11. Stereoscopic diagram of the solar energy heat collector device. 1-automatic exhaust valve; 2-air heat collector; 3-whirlpool flowmeter; 4-box for collecting air; 5-right drying box; 6-electromagnetism valve; 7-gearshift air pump; 8-filter box for parting air; 9-left drying box; 10-thermal insulation airtight door.

diaelata and established the mathematical model of drying in order to select the best drying material method condition [5]. Similarly, the Qinghai New Energy Institute studied the mathematical model of this kind of solar energy dryer drying Chinese wolfberry process and got the best operation parameters [5]. Shanghai Institute of Mechanical Engineering also carried on the related research on the solar drying process of a variety of Chinese herbal medicine.

2.3. The Collector-Greenhouse Type Hybrid Solar Dryer

This kind of dryer structure is shown in **Figure 12**. Drying chamber of this dryer is the same with greenhouse type dryer. It is covered with a transparent glass cover plate and has trays indoor. At work, the material to be dried is put on trays, on the one hand, the solar radiation is absorbed directly from the greenhouse, on the other hand, the solar get hot air from the air heating collectors. This dryer has the advantages of both greenhouse and collector type dryer and comparing with the greenhouse type dryer the dry temperature is improved. When the greenhouse translucent area and collector area is 1:1, the temperature of this dryer could be increased 5°C - 10°C [1]. The collector-greenhouse type hybrid solar dryer is suitable for dry the materials of which have higher water content and need higher temperature to be dried, such as the content of juice of fruit, traditional Chinese medicine with high water content of root and rhizome.

For basic unit using small hybrid dryer, drying chamber is not the simple frame of greenhouse type but only has moisture capacity and plays a role in pumping hot air collector chimney of hot air, so that it would be a trapezoidal shape of elongated box. The lateral of this dryer must be the trapezoidal because the drying chamber of mixed type dryer should have ability to accept large area direct sun radiation. Meanwhile, in order to dry in a desiccator in a hierarchical, the upper layer couldn't block the sunshine of the bottom layer. Therefore, the sunny side of the drying chamber must be designed to favor the incident sunlight with slanted transparent window. In addition, in order to make full use of the morning or afternoon sunshine thermal radiation, the east and west sides of the trapezoidal drying chamber best has windows to increase the amount of incident sunlight. There are insect nets and metal shutters at the bottom of the trapezoidal drying chamber which joint interface thermal air outlet is connected with the air collecting. Comprehensive mentioned in 1 and 2, small hybrid dryer using in basic unit should be a solar drying system which is mixed a high performance air infiltration type honeycomb structure of collector module with a long ladder type greenhouse drying chamber module. During summer and fall, when a large number of high moisture content of traditional Chinese medicine needs to batch drying, the two modules are combined to form a highly efficient hybrid system for bulk dry. In winter and spring, without large drying tasks, the air collector modules can be separately removed and provide heat for residential heating or other production warm air. Because of its independent ventilation drying capacity, the greenhouse-type drying module can be placed in the outdoor sunlight for drying some unfavorable with high temperature drying of Chinese medicinal materials, such as slices or medicine, etc. and also be placed indoors as a traditional Chinese medicine collection box which could be ventilated, breathable and prevent infestation and rat bite [6].

In Dongguan County, Guangdong Province, China, fruit processing company developed a tunnel type greenhouse drying device with air collector. The heat collector area of this device is 31 m² and the greenhouse lighting area is 27 m².

The longan etc. to be dried could be boosted into tunnel kiln of the greenhouse with a car. With fan forced hot

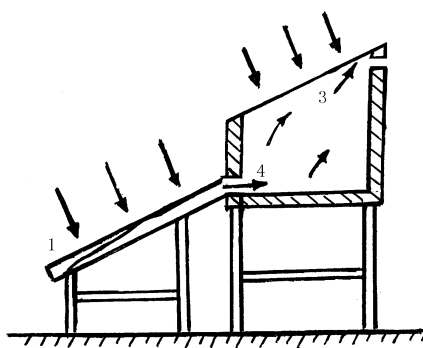


Figure 12. Diagram of the solar energy drying device of mixed model. 1-air heat collector; 2-solar radiation; 3-hothouse; 4-hot air.

air through the material layer, sunny greenhouse temperatures can reach 50°C - 70°C, so that after six days the dried fruit can be out of the kiln. The identification of the drying effect reaches the first grade, at the same time, the drying cycle is short and the quality of the products is improved [2].

2.4. The Integrated Solar Dryer

The integrated solar which is merged dryer solar air collector and drying chamber together as a whole. Trays containing materials are arranged in the drying chamber. The material directly absorbs solar radiation and plays the role of the absorber plate. The air is heated by the greenhouse effect. The drying chamber has axial flow fan so that the air constantly circulates in the two columns in the drying chamber and through the material layer from top to bottom to make the material surface to increase the chances of contact with the hot air. In the integrated solar dryer, the radiation heat transfer and heat convection play a role at the same time so the drying process can be strengthened. The wet air which absorbs moisture is discharged from the exhaust pipe. Through the control valve, the wet air can also makes part of the inlet hot air with supplementary fresh air to circulate and once again goes into the drying chamber to reduce exhaust gas heat loss.

In Wuwei, Gansu province in 1986, the domestic pharmaceutical company built the first building structure type integrated solar drying device applied to Chinese herbal medicine drying [1].

Guangzhou energy research institute of Chinese academy of sciences and the Guangzhou institute of agricultural machinery built an integral solar drying production test device with of the lighting area 187 m² in Guangzhou City suburb of Sanyuanli ruralin 1983. This device could be used to dry the traditional Chinese medicine, red jujube, lotus seeds, dried fruits, etc.

The average daily amount of the material moisture content from 40% to 15% was 1500 - 2000 kg while the max material charge amount was 5000 kg. The device of solar heat utilization efficiency was high and the average daily efficiency went up to 30% - 40% so that the product was dried uniform with good quality [2].

2.5. Focusing Type Solar Dryer

This type of dryer is similar to the ordinary concentrating collectors and usually consists of condenser, the heat absorption tube, tracking system, etc. This dryer can increase the drying temperature, speed up the drying rate, and can greatly improve the insecticidal rate. The disadvantage is that the structure is complex and the cost is high [1].

3. The Comparison of Five Types of Solar Dryer (Table 1)

Table 1. Comparing the advantages and disadvantages of the five types of solar dryer.

Type of dryer	Table Column Head		
	The drying temperature	Advantages	Disadvantages
The greenhouse type solar dryer	≤70°C	Greenhouse type drying system has the advantages of simple structure, low cost, suitable for basic unit to use. This dryer is suitable for the requirements of drying temperature is low and allows direct exposure to the sun's material.	The solar energy drying device of hothouse which efficiency is very low receive the solar total radiation energy effective utilization rate is only 15% used for moisture evaporation materials, mostly lost to the atmosphere.
The collector type solar dryer	≤70°C	This dryer can adjust the temperature of the hot air drying according to the material characteristics; can accommodate more material per unit area, because the material in a dry indoor layer; strength the convective heat transfer so that the drying effect is better. The dryer is suitable for the drugs that could not dry by the sun direct insolate.	Non-permeable air collector with the problems that the top layer of air convection heat absorbing plate or radiant heat loss are more difficult to solve. Permeable air collector had the disadvantages of complex structure, excessive material consumption and complex process. Aggregated air collector with the complex structure does not have the possibility of widespread popularization and application.
The collector greenhouse type hybrid solar dryer	≤70°C	This dryer has the advantages of both greenhouse and collector type dryer and comparing with the greenhouse type dryer the dry temperature is improved. This dryer is suitable for dry the materials of which have higher water content and need higher temperature to be dried	Drying device area and height are larger. The production process is relatively complicated and the cost is also higher.

Continued

The integrated solar dryer	>70°C	In the integrated solar dryer, the radiation heat transfer and heat convection play a role at the same time so the drying process can be strengthened. The wet air which absorbs moisture is discharged from the exhaust pipe. Through the control valve, the wet air can also makes part of the inlet hot air with supplementary fresh air to circulate and once again goes into the drying chamber to reduce exhaust gas heat loss. The device of solar heat utilization efficiency is high.	This dryer cost is relatively high. Drying rate of this dryer is slower than light focusing type solar dryer.
The focusing type solar dryer	>70°C	This dryer can increase the drying temperature, speed up the drying rate, and can greatly improve the insecticidal rate.	The disadvantage is that the structure is complex and the cost is high.

4. Economic, Social and Environmental Benefits and Prospects

Solar energy is a pollution-free natural energy, its social and environmental benefits can be summarized as follows. 1) The solar energy could save coal and power, and reduce environmental pollution. Natural convection greenhouse type dryer dries things by solar heating 100%. As the forced ventilation greenhouse type dryer, the power consumption of the fan accounts for only 5% of the total energy. The heat dryer which combined the solar energy and conventional energy can be saving energy more than 20 to 40 percent; 2) The product is clean with particularly good color, smell and taste. Because of the hot strong penetrating power, the drying effect is good that is positive significance to improve the quality of drugs and clinical curative effect; 3) It is suitable for using in remote areas and grass-roots units; 4) The solar energy can shorten the drying period of Chinese herbal medicine natural drying and improve workers' working conditions and production efficiency.

That the all glass vacuum tube solar collector and heat pipe-glass vacuum tube being published has greatly promoted the development of the solar thermal utilization and has been widely used in the field of solar water heaters which is developing rapidly in our country. However, efficient vacuum tube heat collection technology in air collector has not been reported in domestic. In foreign, the United States, Israel and other countries have mainly explored [1] while the popularization and application is very few. Therefore, at the background of the mass production and the promotion of the vacuum tube solar collector in our country, development and production the high efficiency, low price of two end tube air heating element or other forms of vacuum tube heating element is the key to the development of high efficiency air collector and to use it to create modules solar air collector. Or combining with the flat air collector to develop practical strong solar dryer, combining with adsorption and regeneration technology, also supplying air-conditioner cooling, heating and other services, all of these will have significant social and economic benefits.

References

- [1] Zhang, J.G. (1999) Review on the Development of Solar Energy Dryer. *New Energy*, **21**, 30-34.
- [2] Li, J.H. (1999) Application of Solar Dryers in Our Country. *Solar Energy*, **1999**, 23-24.
- [3] Xu, C.X. and Ning, W. (2004) Introduce the Simple Solar Wood Drying Chamber. *Forestry of China*, **55**, 38-39.
- [4] Liu, M.L. and Li, K.R. (2005) Investigation of Simple Box Type Solar Cooker Drying Slices. *Chinese Journal of Hospital Pharmacy*, **25**, 580.
- [5] Liu, S.Y. and Li, L.D. (2000) Utilization of Solar Drying and Its Application in Industrial and Agricultural Production. *New Energy*, **22**, 9-15.
- [6] Tu, J.M. (1992) The Design Problem of the Household Solar Dryer. *Journal of Yunnan Normal University (Natural Sciences Edition)*, **12**, 1-4.
- [7] Zhou, W.L. and Luo, X.G. (1986) Application of Solar Collector Drying Device in Traditional Chinese Medicine Pills. *Chinese Traditional Patent Medicine Research*, **1986**, 36.