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Fixed bed drying of medicinal plants using dehumidification of air

Drying of medicinal and spice plants is highly energy-consuming and cost-intensive. Hence, a procedural manner for batch-type fixed bed drying was developed where heat pumps are combined with conventional air heating by natural gas or fuel oil. Industrial application was realized in cooperation with two large agricultural companies in Thuringia. Compared to conventional air heating, energy savings of up to 50 % are possible when heat pumps are equipped with internal heat recovery and waste heat from combined heat and power plants is used.

Keywords

Drying, heat pumps, heat recovery, energy efficiency, medicinal plants

Abstract

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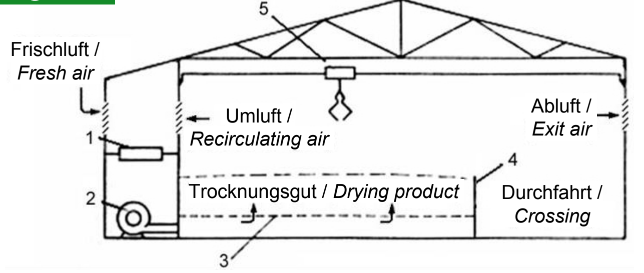
In Germany, more than 100 different sorts of medicinal and spice plants are grown on approx. 10,000 ha total production area. They are classified as herb drugs, flower drugs, fruit drugs, or root drugs depending on the part of plant containing the active substance. Due to the variety of sorts, dryers of different designs are employed in harvesting periods from May to October. Cabinet dryers are mainly used for small or medium size production. When large mass flows are processed continuously operated belt dryers or large-scale fixed bed dryers working in batch operation are required. Belt dryers are frequently used for products that are cut before drying, e.g. parsley [1].

Medicinal and spice plants are produced by highly specialized agricultural companies, usually equipped with only one dryer design type. Particularly in the eastern federal states of Germany large fixed bed dryer systems have a longstanding tradition (**figure 1**). Key advantages of this powerful multiple purpose drying method are the comparatively simple structure of the dryer, the immediate drying without interim storage, and the relatively low labour demand. As yet, a main disadvantage is the high specific energy demand (up to one liter of fuel oil, or an equivalent effective amount of natural gas per kg of dried material) due to uneven air flow distribution, inhomogeneous bed material distribution on the drying grates, insufficient air circulation and high heat loss [2].

Fig. 1



Schematic of a fixed bed dryer:
1 = Heat exchanger, 2 = Radial fan, 3 = Perforated floor, 4 = Grate border, 5 = Gantry crane with grabber

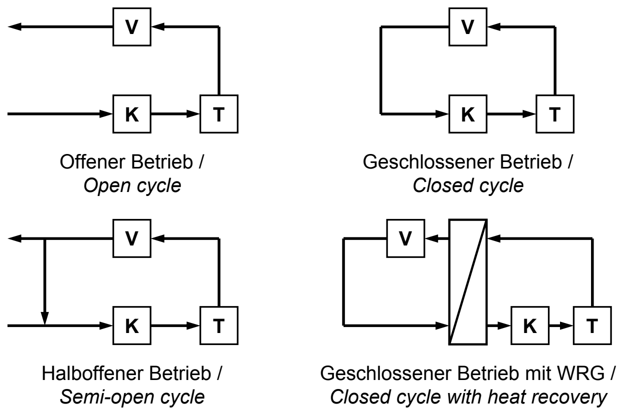
Heat pump drying

In conventional fixed bed dryers, the drying air is usually heated using natural gas or fuel oil. To minimize the loss of essential oils, a drying temperature of approx. 40 °C should not be exceeded. At this temperature level, heat pumps can be operated at high performance numbers. However, high investment costs require an accurate design and professional operation of the heat pumps in order to fully utilize the economical benefits of energy savings.

Since the early 1970s the interest in using heat pumps for the drying of miscellaneous products has been growing continuously [3–5]. For several years, heat pumps are also increasingly used for the drying of medicinal and spice plants [6–10]. Regarding the air flow arrangement, a variety of potential connections exists. A selection of them is schematically depicted in **figure 2**. The exhaust air from the dryer is used as heating source for the evaporator of the heat pump, where it is cooled down and dehumidified by falling below the dew point. At a closed cycle operation, the drying air is completely recirculated and heated up to the required drying temperature in the condenser of the heat pump. When the heat pump dryer is appropriately heatinsulated, it operates widely unaffected by external climate conditions and can be controled particularly energy-efficient during the night. The circuit of the cooling medium is not shown in the figure to avoid confusion.

A major advantage of the closed cycle operation with internal heat recovery is that it substantially increases the energy efficiency. Using a plate heat exchanger between the exhaust air

Fig. 2



Selection of air flow arrangements appropriate for heat pump drying: K = Condenser, T = Dryer, V = Evaporator

from the dryer and the air from the evaporator which has been cooled down and dehumidified, the required cooling power of the evaporator decreases. As a result, the driving power for the cooler compressor is considerably reduced. As the exhaust air temperature increases during the course of the drying process the amount of heat recovered increases as well. Consequently, as the drying proceeds increasing energy savings can be realized at constant heat supply of the heat pump. A respective semi-technical test dryer was developed at ATB and set into operation in 2009. Numerous drying tests conducted with diverse medicinal plants confimed the results from theoretical studies [10].

Industrial implementation of the combined drying process

Since the specific energy demand is increases during the course of drying, the air heating should be switched to conventional methods at a certain point of time. Hence, in a daily sequence one heat pump can be employed for several dryers. This substantially reduces investment costs for the entire drying plant. The respective drying times for the different products should be considered in the plant design. The same applies to the operational variants preferred by the respective agricultural farms.

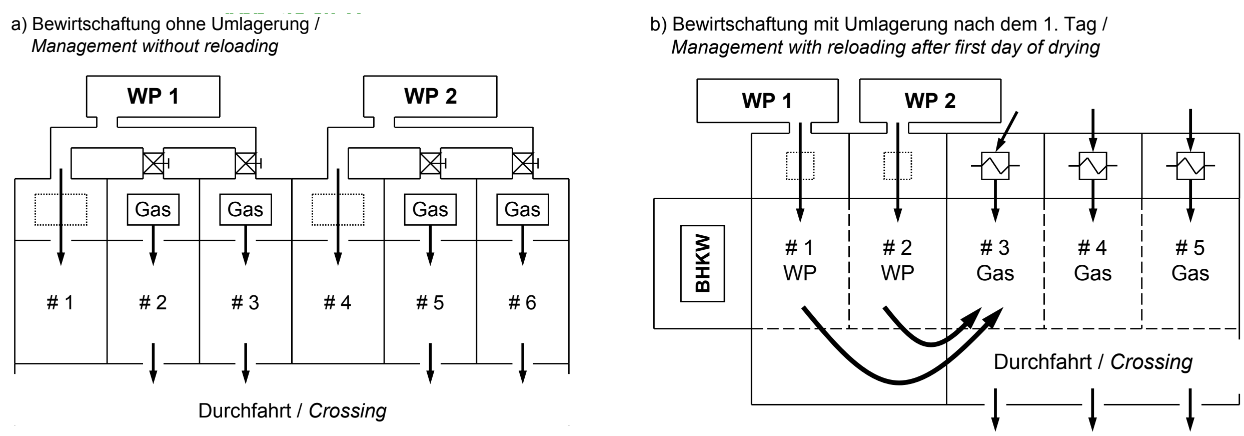
The fixed bed drying of medicinal and spice plants takes 3–4 days depending on the product. The height of the bed material varies between approx. 0.5 and 1.2 m. Flower drugs like chamomile are usually dried within three days. Herb drugs such as peppermint or melissa require approx. four days of drying because they are dried as whole plants and, thus, the stems need complete drying as well. To save energy herb drugs can be relocated after 1–2 days and reloaded on about half size of the gratearea. This is impossible for chamomile flowers.

Figure 3 shows the diagram of two fixed bed dryers for medicinal and spice plants in Thuringia. Drying plant (a) was designed for chamomile flower drying and consists of two equal partial systems. The main components for each system are three drying grates, three gas heaters, and one electric heat pump. At the first day of drying, both heat pumps are used for air heating (closed cycle with dehumidification), and subsequently conventional air heating is employed for the 2 days left. Every day, the heat pumps are switched via a system of air ducts and flap valves to the respective drying grates which have been loaded with fresh goods. In this manner a three-day cycle is created. The total grate area amounts to approx. 312 m². At a capacity of about 1.2 t of dried goods per day, energy costs were cut by more then 30% in the first year of operation (2007).

Drying plant (b) was designed for whole-plant-drying of herb drugs, which were swapped on the second day of drying from the heat pump cycle grates 1 and 2 to the conventional drying grates 3, 4, or 5. Thus, a four-day cycle was established. The total grate area of the modernized storage depot is approx. 340 m² and was commissioned at the harvesting season 2010.

Both heat pumps are equipped with a highly efficient internal heat recovery system. The air heating at the conventional drying grates 3, 4, and 5 is facilitated by way of existing heat exchangers, which are connected to a central heating. Additionally, a combined heat and power plant powered by natural gas was installed. In contrast to large scale thermal power plants,

Fig. 3



Simplified schematic of two fixed bed drying plants: WP = heat pump, Gas = gas heater, BHKW = combined heat and power plant in which about two thirds of utilized primary energy is wasted, the waste heat of a combined heat and power plant can be used to reduce fuel consumption in the conventional drying phase. Moreover, the comparatively dry and warm exhaust air from the conventional drying area can be utilized as inlet air for another drying hall (not depicted).

Conclusions

Energy savings of up to 50 % can be realized. Particularly when the production is extended, such investments will have payback periods of only a few years. Thus, in the medium term capacity and competitiveness of the German medicinal plant and herb production will be enhanced.

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