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DRYING OF HERBAL PLANTS AS A METHOD OF MANAGEMENT OF WASTELAND

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ABSTRCT: The cultivation of herbs in Poland is one of the newest sectors of plant production despite the centuries-old tradition of using herbs across the world. Contemporary herbal processing in Poland is primarily oriented to the production of herbal medicines, as in many other European countries. The cultivation, harvesting and processing of herbs in small and medium-sized farms require machinery and devices adjusted to the scale of production. The processing of herbal plants involves drying, which is one of the most important stages of herb preservation and the most energy-consuming process occurring in agricultural production. A comprehensive review is presented covering the various methods used in agriculture to preserve herbal plants and the classification of solar-energy and hot-air drying systems. In addition the paper presents examples of the development of solutions using low-temperature herb dryers appropriate to small and medium-sized farms.

KEY WORDS: dryer, herbs, herbal plants, solar collector

JEL: O13, Q16, Q55

Introduction

Herbs are characterised by different contents of biologically active substances and hence they are widely used in various branches of industry. Formerly herbs were used in folk medicine, now they are widely used in the herbal, pharmaceutical and food industries (spices, juices), cosmetics (creams, pastes) and perfumery. The content of biologically active substances in herbal plants includes various types of chemical compounds such as: anthocyanins, flavonoids, glycosides, alkaloids, saponins, and tannins. In the group of herbal raw materials, we can distinguish seeds (*semen*), rhizomes (*rhizoma*), leaves (*folium*), roots (*radix*), flower (*flos*), fruit (*fructus*) and cortex (*cortex*). Herbs include species from which it is possible to obtain one or more types of raw material. For example, nettle (*Urtica dioica L.*) is a source of leaves and roots.

About 130 species of herbal plant are cultivated in Europe on a large-lot scale of production, and the area of herbal plants under cultivation in the European Union countries is about 70,000 ha.On a world scale about 20 thousand species are used for therapeutic purposes (Olewnicki et al., 2015). Herbal plants cultivated in Poland come from field cultivation and natural sites (Seidler-Łożykowska, 2009). There are about 2500 species of herbal plant cultivated in Poland, and the Polish herbal industry uses about 160 species.

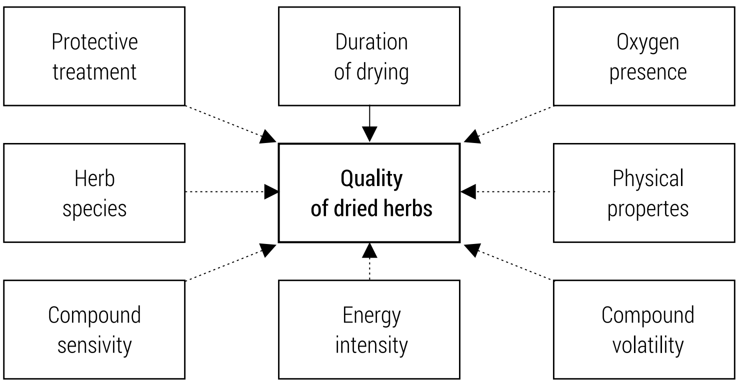

Figure 1. Factors affecting the quality of dried herbs

Source: authors' own work based on (Orphanides et al., 2016).

Drying is the most commonly used method for the preservation of agricultural products. Among the factors affecting the quality of herbs after harvesting, the conditions related to the stabilisation of the raw material and the process of its storage should be mentioned. Stabilisation is mainly related to the drying process, which should be carried out under appropriate conditions that do not reduce the quality of the raw material. The temperature and drying time should be adapted to the specific plant species. Various factors that influence the final quality of dried herbs are presented in figure 1.

This article discusses the devices available for the mechanisation of herb cultivation and presents examples of proposed solutions for herb dryers destined for small and medium-sized farms. The possibility of using low-temperature heat produced by solar collectors for drying purposes is also presented.

Methods of drying

The methods of drying herbs are presented in figure 2. Traditional methods have been used such as open-air sun and solar drying, with, respectively, direct and indirect use of solar energy, and/or shade drying (Orphanides et al., 2016). On a smaller scale, freeze drying, convection drying with hot air and ultrasound assisted drying methods have also been used. Hot-air drying and shade drying are widely used due to their low cost (Soysal, 2004).

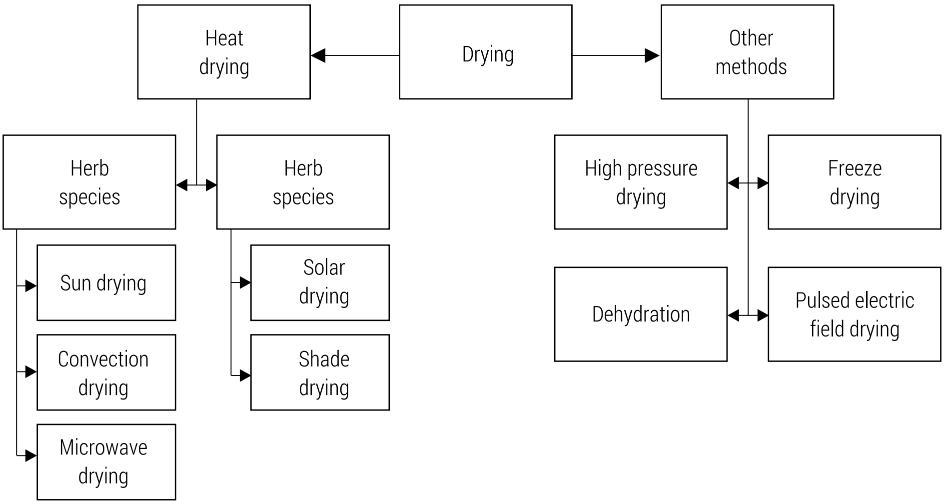

Figure 2. Methods for drying herbs

Source: authors' own work based on (Orphanides et al., 2016).

Drying in the sun is one of the oldest methods of drying utilising solar energy. It is widely used to dry agricultural products, such as medicinal plants, across the whole world (Janjai, Bala, 2012). Solar dryers can be categorised into direct and indirect (Sharma et al., 2009; Shylaja, Peter, 2004).

Both natural methods (active and passive), using the heat of solar radiation and heat contained in the air directly, as well as thermal – mainly convection drying, are used (Argyropoulos, Müller, 2014).

The working principles of drying in the open sun, direct solar drying and indirect solar drying are presented in figure 3. Part of the solar energy is absorbed by the crop surface and the remaining part of the solar energy is reflected back into space (figure 3a). Converted absorbed radiation causes an increase in the crop temperature and its loss to the environment. Blowing a draught through the moist air over the crop surface also contributes to convective heat loss. During direct drying (figure 3b) a part of the solar radiation passes through the transparent cover and is reflected back to the atmosphere. The remaining part of the solar radiation is transmitted inside the dryer and is reflected back from the crop surface. In indirect solar drying (figure 3c) the crop is kept in the drying chamber. The solar air heater is used for solar-energy collection and the heating of air entering into the heater which is connected to the drying chamber. The warm air is transmitted across the crop. The heat from moisture evaporation is provided by convective heat transfer between the warm air and the wet crop (Sharma et al., 2009). The crop is dried by the difference in moisture content between the drying air and the air in the vicinity of the crop.

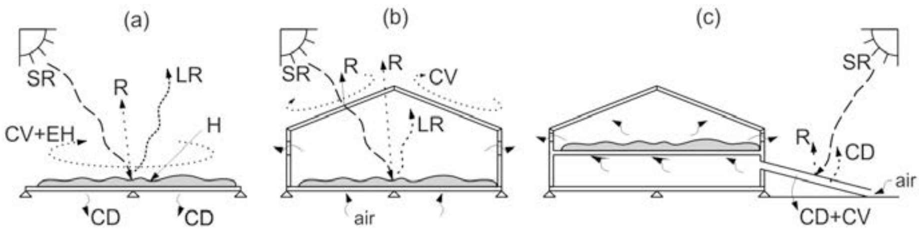

Figure 3. Working principles of (a) open sun drying, (b) direct sun drying and (c) indirect solar drying: CD – conductive losses, CV – convective losses, EH – evaporative heat losses, H – heat absorbed, L – low wavelength radiation, R – radiation, SR – short wavelength solar radiation

Source: authors' own work.

To avoid the direct exposure of herbs to the sun, the shade drying of herbs has been associated with a higher quality product than sun drying. The drying period in shade drying is longer than in the case of sun drying (Pirbalouti et al., 2009). Solar energy is utilised to heat air that then passes through the material by the use of suitable equipment (Sharma et al., 2009). The limitations of solar drying are the climatic conditions. Rainy weather conditions lead to a susceptibility to rehydration of the dried product.

Hot-air drying using convection ovens is a basic technology for postharvest preservation of aromatic and medicinal plants (Müller, 2007; Antal et al., 2011). Infrared and microwave waves enhance conventional drying and reduce the drying time compared to conventional methods.

Proposals of driers for small-scale production

Agriculture is characterised by a significant number of energy-consuming technological processes.This situation is most often caused by the need to maintain the kinetics of the drying process of large amounts of raw material with high humidity.In the case of drying bulk materials, the problem is to construct a dryer to achieve and maintain the desired drying parameters (surface, humidity, temperature) in the dryer, with a minimum amount of drying agent supplied.The classical examples in this area are hay and herb dryers. The years 60-90s of the 20th century formed, among other things, a period of intensive investigation on drying processes in the preservation of agricultural products (Niemiec, 1995; Niemiec, Michna, 1991). The simple field and farmhouse hay dryer constructions (figure 4) used local materials such as waste wood.

The drying of herbs takes place under a so-called low- or medium-temperature convection drying process, with air temperature not exceeding 40^{o}C. Under these conditions, solar collectors may be an alternative to other artificial drying methods (Baniasadi et al., 2017; Janjai, Tung, 2005). Heat demand for drying purposes occurs during the harvest period for herbs and coincides with the period of the highest solar radiation. In air collectors, the air is the working medium. To use solar collectors rationally the following factors should be taken into account:

- structural features that can be used during construction (rafter framing, type of roofing),
- process conditions (location of drying room, dryer size, type and amount of dried material).

Drying equipment can be divided according to different criteria, e.g. taking into account the drying mechanism: convection dryers (moisture from the material is reduced by a stream of drying gas) and contact driers (the material is in contact with the hot surface of cylindrical chambers). Achieving economically justified drying kinetics is, first of all, defining the purpose of drying, knowledge of the physical and chemical characteristics of the dried material and its quantity, and proper selection of the type of dryer and the details of its construction.In the case of the location of the dryer, taking into account the heat source planned to be used in the drying process and land hypsography will permit many errors and hence costly losses in the process to be avoided.

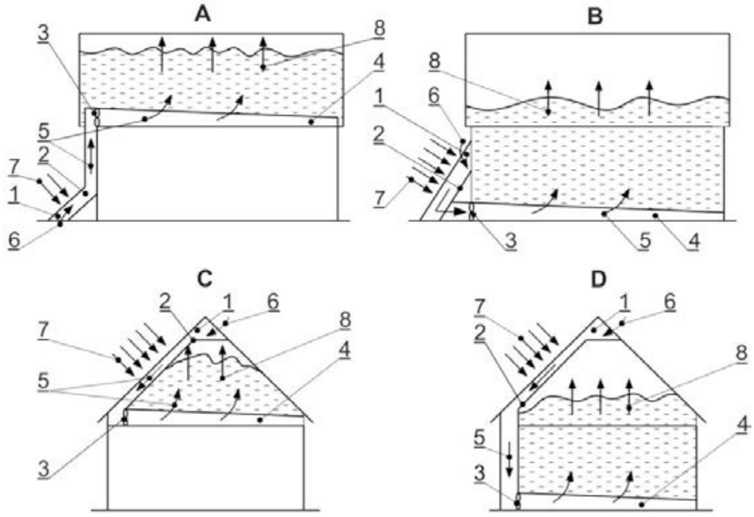

Figure 4. Basic rules for installing solar collectors in farm buildings; A – wall collector with drying room in the loft, B – wall collector with dryer in the barn, C – under floor collector with drying room in the loft, D – under roof collector with drying room in the barn: 1 – air inlet, 2 – collector, 3 – fan, 4 – distribution channel, 5 – heated air, 6 – ambient air, 7 – solar radiation, 8 – humid air

Source: authors' own work.

During the storage of hygroscopic materials and poorly carried out drying processes, conditions fostering spontaneous combustion may occur, e.g. in the case of coal storage, bulky feeds (storage of damp hay in barns) and other cases found in biochemical processes implemented in industry and the processing of agricultural raw materials.In the case of herb drying, the temperature regime and the influence of the intensity of solar radiation (UV) are of particular importance.Looking for ways to reduce energy consumption in crop drying, in particular bulky feeds and herbs, solar collectors have been developed (figure 4) which have a heating unit (figures 5 and 6) for heating the drying air in herb driers. Depending on the atmospheric conditions and the required drying parameters, the dryer is fed from the solar collector or the heating unit. In order to maximise the use of solar radiation energy, the air is always supplied to the heating unit after preheating in the collector (figure 4). After flow through the collector, the air is supplied to the combustion chamber in the heating unit and to the heat exchange chamber located between the combustion chamber and the air inlet into drier. In the case of favourable atmospheric conditions (temperature, humidity), the air heated in the collector can be fed directly to the dryer.

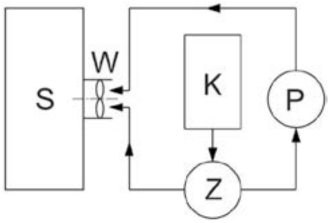

Figure 5. Block diagram of the installation of the equipment in the dryer: S – dryer room, W – fan, K – solar collector, Z – three-way gate valve, P – heating unit

Source: authors' own work.

Improvement of the temperature control of the air supplied to the heat exchanger is obtained by changing the number of sections of the flue. The flue consists of at least two sections connected to each other. The sections are made of a flexible metal tube coiled in conical spirals with at least two coils. The control of the heat exchange surface is possible by changing the number of sections mounted. The biomass stove used in the heating system with a variable heat exchange surface allows the temperature of the heated air to be more easily maintained and, as a result, to be adapted to the weather conditions and the requirements of the dried material. The heating unit for heating the air contains a combustion chamber, with a mounted burner, which is separated by a plate from the heat exchanger (figure 7).

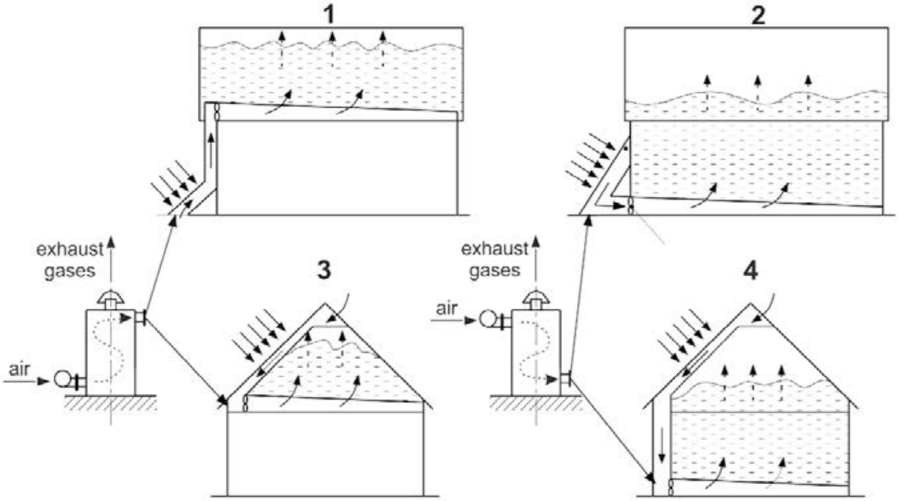

Figure 6. The principle of cooperation of a heating unit with dryers equipped with solar collectors in an attic and in a barn: 1, 2 – wall collectors; 3, 4 – under-roof collectors

Source: authors' own work.

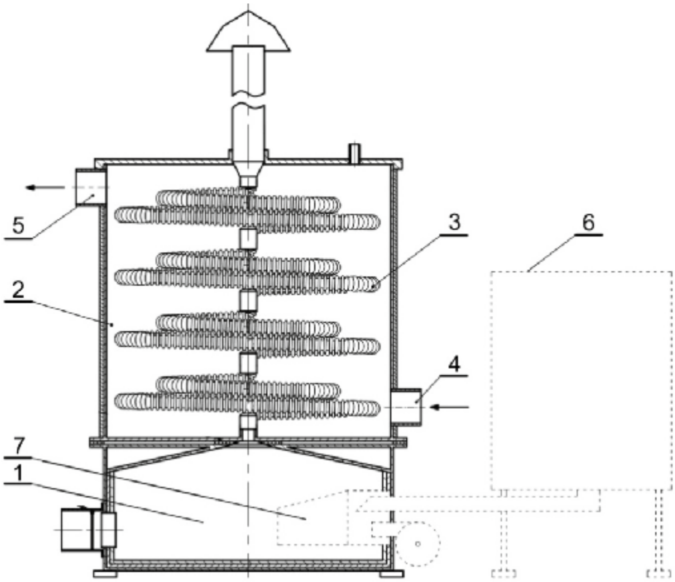

Figure 7. The air heater equipped with biomass stove: 1 – combustion chamber, 2 – heat exchanger, 3 – tubular section of flue, 4 – air inlet, 5 – air outlet, 6 – biomass heating unit with biomass-storage cell, 7 – burner

Source: authors' own work.

The device thus developed is currently under patent procedure. The prototype of the air heater is in the process of manufacture. The combustion chamber is insulated from the walls of the heat exchange chamber by two insulating layers, one of which is a chamotte layer and the second is a vermiculite layer. When the burner is fed with woodchips or pellets, effective combustion of these heating fuels is obtained if the burner is equipped with a fan.

The main advantages of the air heater presented here include the possibility of adjusting the length of the flue by changing the number of spiral sections, as a result of which the heat exchange surface between the flue gas and the heated air is altered. This solution permits the temperature of the heated air to be regulated and thus to be adapted to the needs of the dryer, as well as controlling the value of the negative pressure that causes the flue gas to flow through the heat exchanger.

The heater is particularly useful for drying agricultural products, herbs and spices. In addition, the heater has a simple structure and is cheap to fabricate. The construction of the stove unit enables both forward-current and counter-current heat exchange, and the conical design of individual sections of the flue ensures good gas circulation. The stove permits the combustion of various forms of biomass; the preferred types of biomass are wood chips and pellets.

The air heater presented in this paper is easy to build and inexpensive to operate, which provides the opportunity for its widespread use by herb producers and for the drying of other agricultural crops. The use of a segmented grate permits quick disassembly and, if necessary, an adaptation of the drying chamber for drying other materials such as, for example, grains. There are many opportunities to construct simple and cheap solar collectors. In figure 8, a collector located on a cowshed wall is shown. The collector is constructed with the specification of obtaining the optimal solar radiation on the surface of the foil collector, the roof slope of a barn or a livestock building (Niemiec, Król, 1994a).

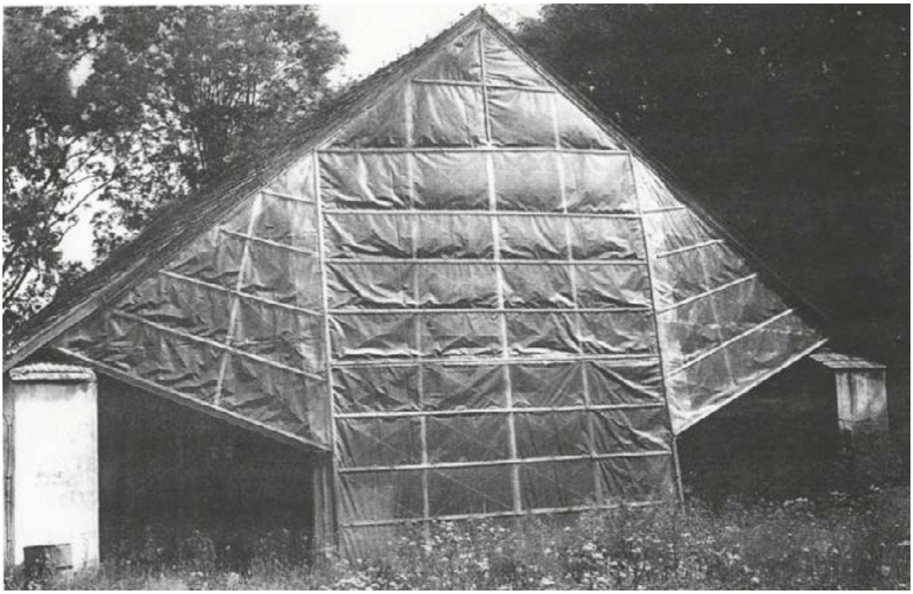

Figure 8. A wall collector for drying agricultural products
Source: (Niemiec, Król, 1994b, p. 1).

Conclusions

In order to obtain high quality herbal raw materials during the drying process, it is necessary to maintain the basic technological parameters (time, temperature) close to the natural conditions prevailing in nature. Under roof solar collectors are recommended for use when there is favourable insolation on roofs covered with sheet metal or tiles. If there is an unfavourable location of the roof surface in relation to the sun, wall collectors can be used effectively. The benefit of drying herbal plants in buildings equipped with solar collectors is to eliminate the harmful effect of ultraviolet solar radiation and minimise the loss of ethereal oils. The use of collectors in driers also allows farmers to become more independent of weather conditions, and thus to plan work on the farm in a rational manner.

The contribution of the authors

Witold Niemiec conceived and designed the structure of the article. Tomasz Trzepieciński performed the review of literature. Both authors contributed equally to developing the air heater and to the writing of the paper.

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