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Experimental investigation of an indirect solar dryer integrated with phase change material for drying valeriana jatamansi (medicinal herb)

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ABSTRACT

In this study, an experimental investigation of an indirect solar dryer integrated with phase change material has been carried out for drying *Valeriana Jatamansi*. The experimentation has been performed under the climatic conditions of Himalayan region, Solan (latitude – 30.91°N, longitude – 77.09°E), Himachal Pradesh (India) in the month of October-November 2016. Paraffin RT-42 has been used as a phase change material in the dryer. Using this system, the moisture content of rhizomes reduced from 89% to 9% in 5 days as compared to heat pump drying and shade drying, which took 8 days and 14 days, respectively. Results of present study infer that the drying time using phase change material in this setup has reduced by 37.50% and 64.29% when compared to heat pump drying and shade drying, respectively. The dried rhizomes obtained are of superior quality in terms of colour, texture, aroma and bio-medical constituents. Analyses show that by using present setup, total valepotriates obtained were 3.47% as compared to traditional shade drying which yield 3.31%.

1. Introduction

Drying is considered as the oldest technique to preserve agricultural based products and medicinal herbs. In this process, moisture content is reduced to its saturation level. Heated air is utilized by natural or artificial means and moisture concentration gradient thus created causes the movement of moisture from inside to outer surface of the product. Temperature more than the acceptable limit causes both physical and chemical changes and ultimately deteriorates the quality of the dried product. Air supplied at controlled temperature enhances their storage life, minimizes loss and saves transportation cost as most of the water contents are dehydrated [1–3]. Dehydration of such products is necessary to avoid bacterial and fungal growth.

Belessiotis et al. [4] investigated solar drying of agricultural based products and analyzed that drying under controlled limits of temperature allows the product to dry rapidly to safe moisture level and ensures the product of superior quality. Ekechukwu et al. [5] studied the solar energy drying system and analyzed that the acceptable temperature of hot air for safe drying of product depends on its composition. Pangavhane et al. [6] investigated the performance of a natural convection solar dryer and analyzed that the energy requirement for drying products depends on the amount of moisture to be removed. High cost of coal and fossil fuels, ecological impacts and gradual diminishing trends of their reserve have imposed serious constraints on their use and have emphasized the use of some other form of energy which is renewable, abundant, eco-friendly and has less adverse impact on the environment. Purohit et al. [7] compared the performance of solar drying methods with the traditional drying and evaluated the financial aspects.

Kant et al. [8] studied the contributions made in the field of solar drying system based on the thermal energy storage medium,

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Nomenclature

A_c	Area of collector, (m^2)
I	Solar intensity, (W/ m^2)
LHS	Latent heat storage, (J)
M	Mass, (kg)
m_a	Mass flow rate of air, (kg/s)
m_w	Moisture evaporated in time t, (kg/s)
P_f	Energy consumption of blower, (kWh)
PCM	Phase change material
PU	Polyurethane
Q_c	Energy absorbed by the collector, (kWh)
RC	Rehydration capacity
SHS	Sensible heat storage, (J)
SMER	Specific moisture extraction rate, (kg/kWh)
SR	Shrinkage ratio
T	Temperature, (°C)
t	Drying time, (sec)
s	Dry matter content, (%)

Subscripts:

c	collector
a	air
d	dry
f	final
i	initial
o	original (before drying)
r	rehydrated
th	thermal
w	wet basis

Greek

η	efficiency, (%)

capable of storing heat as sensible and latent heat. EI-Khadraoui et al. [9] designed and investigated the feasibility of solar air heater with PCM to store solar energy during the day time, and release it at night. Esakkimuthu et al. [10] investigated the feasibility of latent heat storage (LHS) unit with an HS 58 (inorganic salt based phase change material) to store the excess thermal solar energy and release it overnight as well as during poor weather conditions. Shalaby et al. [11] studied the applications of paraffin wax as a thermal storage medium and noticed that PCM reduces the heat loss and improves the efficiency of the system. Teng-yne et al. [12] utilized lauric acid as a PCM and investigated the collector charging and discharging time of thermal storage device through different air volume flow rates. Rabha et al. [13] studied the performance of drying of chilli in a forced convection solar dryer integrated with paraffin wax as a latent heat storage medium and found improvement in drying efficiency. Agarwal et al. [14] investigated the suitability of paraffin wax as a latent heat storage material for solar drying applications and evaluated on the basis of the results. Sharma et al. [15] investigated phase change materials (PCMs) for low temperature solar thermal applications and observed improvement in quality of the product.

Soysal et al. [16] studied the effect of drying techniques on the medicinal herbs and found the dehydration process as a critical threshold to preserve the product for a longer time. Khalid [17] et al. investigated the influence of drying temperature, humidity and drying time on the medicinal herbs and observed that these parameters greatly affect the essential oil present in the product. Agah et al. [18] studied the effect of drying temperature, humidity and drying time on the medicinal herbs and found that these parameters significantly affect the essential oil present in the product. Fathi et al. [19] investigated the influence of drying techniques on important ingredients of essential oil and observed that all active constituents are retained using drying techniques in the shade. Rocha et al. [20] studied the influence of drying process on the medicinal plants and analyzed that volatile compounds are sensitive to temperature difference. Choudhary et al. [21] experimented solar drying of horticulture products with PCM and found this technology effective for preservation of medicinal plants. Jain et al. [22] developed an indirect solar crop dryer with phase change material to maintain continuity of drying herbs for their colour and flavor vulnerability.

Some of the medicinal plants are considered as heat sensitive and require drying under controlled conditions; otherwise the quality will deteriorate [23]. Literature review of solar drying of medicinal plants and herbs is presented in Table 1.

Medicine is an essential requirement of all human beings. *Valeriana Jatamansi Jones* is an aromatic as well as medicinal crop. Miyasaka et al. [37] experimented valeriana in the treatment of nervous state and anxiety-induced sleep disturbances. Grunwald [38] studied the use of valerian extracts as dietary supplements. These supplements are primarily composed of dried roots or its extracts, formulated into tablets or soft gelatin capsules. Each dose contains approximately 50 mg of dried root or its extract. Spinella [39] analyzed the treatment of epilepsy using valerian and recommended it for use. Muller et al. [40] observed that valerian tends to sedate the agitated person, stimulates the fatigued person and brings about a balancing effect on the system. Mathela et al. [41] studied its commercial importance and found it as a substitute for *Valeriana officinalis* in India, Nepal and in the Himalayan region. Kaur et al. [42] investigated the composition of its fresh underground parts for medicinal use and analyzed that rhizome and root yield essential oil, which is important in world trade. Woerdenbag et al. [43] examined the influence of post harvesting process on the quantity and quality of important active ingredients in the dried product and observed that it greatly affects the production chain. The herb is required to process locally due to its perishable nature, scattered plantation, means of preservation and difficulty in transportation to nearby markets. Fennel et al. [44] investigated the influence of dehydration rate on the safe storage of herb and found drying as an essential part which aims at decreasing moisture content, avoiding enzymatic and microbial activity, and as a result preserving the product to extend shelf life. Calixto et al. [45] studied the positive consequences of drying process and observed that effective dehydrating method contribute to a regular supply and facilitate the marketing of medicinal product by reducing the weight and volume of the herb.

The unstable nature of valepotriates due to their sensitivity to light, heat and humid conditions affects their concentration. So, collecting the raw material from the production areas and then processing the same at nearby sites helps in avoiding enzymatic and