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Drying Characteristics of Foam-Mat Dried Wood Apple (*Limonia acidissima*)

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ABSTRACT

Wood apple (*Limonia acidissima*) is indeed a highly nutritious but underutilized fruit, particularly prevalent in arid regions. Its potential for reducing waste and enhancing food security is significant if processed and preserved effectively. This study evaluated the drying kinetics of foam-mat drying for wood apple, using 8% GMS as a foaming agent and 0.5% methyl cellulose as a foam stabilizer. The mixture was whipped for 10 minutes and dried in a cabinet dryer at varying temperatures (55, 60, and 65 ºC) and air velocity (2m/s, 2.5 m/s) at foam mat thicknesses of 2 mm. Drying kinetic data such as moisture content, moisture ratio and drying rated were studied. The results showed that the increase in drying time, temperature and air velocity would reduce the moisture content while at the same time, drying rate increased significantly.

Key words: *Wood apple, Foam mat drying, Drying kinetics.*

Introduction

Wood apple belongs to the family Rutaceae Swingle (*Limonia acidissima* L.; *Schinuslimonia* L.). It is also called elephant apple, monkey fruit, curd fruit, vilampazham, kathbel and kaithain India.It is used in many herbal remedies such as digestive, stimulant, astringent, carminative and as an antidiarrheal. It contains a number of phyto constituents. The raw fruit pulp is helpful in the treatment of gastro intestinal problems like flatulence, diarrhoea, dysentery and piles.

Wood apple is mainly seasonal crop available in winter season from October to February. The fruit after ripening causes fungal attack. So, to reduce post-harvest losses of wood apple, conversion into a value-added product that is available all year. Drying of pulp can be one of the best methods of preservation.Drying is one of the most commonly applied processing routines for sustaining quality in food products due to its effectiveness at facilitating handling, transportation, and storage (Singhal *et al.*, 2020).

Thin-layer drying principles are widely used to understand the fundamental of transport mechanisms (Inyang *et al.*, 2018). Increase in drying time decreases the moisture content of the sample and simultaneously increases the drying rate. High temperatures would reduce the drying time and increase the drying rate. Air velocity also can influence the drying process in which the increased air velocity would decrease the moisture content of the

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sample as the drying and evaporation rate increase (Shahari *et al.*, 2016; Dereje and Abera, 2020).

Foam-mat drying is an innovative technique for drying liquid food materials with high water content, making it ideal for heat-sensitive, viscous, sticky, or otherwise difficult-to-dry fruits and vegetable extracts. In foam-mat drying, aqueous food concentrates are dried using air at lower temperatures to reduce moisture content, forming a stable, honeycomb-like porous sheet that can be milled into powders. Keeping all this in view the present research was conducted with following objective; To study the drying characteristics of foam-mat dried wood apple.

Materials and Methodology

Sample preparation

The fruits were broken with the help of hammer and the pulp was extracted from it. After extraction of pulp the pre-treatment was given with hot water blanching at 80 ºC for 5 minutes then addition of KMS 0.5 per cent in pulp. Foaming was done with help of electric hand blender with addition of 8% GMS (glycerol-mono-stearate) as foaming agent, and 0.5 % MC as stabilizer then blended with hand blander at maximum speed for 10 min.

Drying process

The hot-air drying process was carried out in a cabinet dryer. The foamed pulp was dried at air temperature of 55, 60, 65°C with foam thickness of 2 mm in a cabinet dryer at two air velocity 2 m/s and 2.5m/s. All drying experiments were carried out in triplicate. Samples were placed as a thin-layer in a stainless-steel tray. Experiments were performed until an equilibrium condition was achieved and a constant weight of the samples was registered. The dried samples were ground in powder form then kept in sealed polypropylene bags.

Drying kinetics

Moisture content

The moisture content of wood apple samples was determined by using hot air oven method. The moisture content of the sample was determined by using the following formula.

$$Moisture\ content\ \%\ db = \frac{W_1 - W_2}{W_2} \times 100 \quad ..(1)$$

Where,

W_1 = Initial weight of the sample (g)

W_2 = Final weight of the sample (g)

Moisture ratio

The Moisture Ratio (MR) was calculated by using the following Eq. 2 (Aghbashlo *et al*., 2009)

$$MR = \frac{M - M_e}{M_0 - M_e} \quad ..(2)$$

Where,

M= Moisture content at time t (min) during drying (% d.b.)

M_e= Equilibrium moisture content (% d.b.)

M_o= Initial moisture content ((% d.b.)

The values of M_e were neglected because when compared to M_o and M the values of M_e (equilibrium moisture content) were very small for long drying time. Therefore, the following Eq. 3 was used to calculate the MR.

$$MR = \frac{M}{M_0} \quad ..(3)$$

Drying rate

The drying rate (DR) is defined as the quantity of moisture that evaporates over time (Nguyen *et al.* 2019). The drying rate of sample was calculated by using the following Eq. 4. (Aghbashlo *et al*. 2009).

$$Drying\ rate = \frac{M_{t+dt} - M_t}{dt} \quad ..(4)$$

Where,

M_{t+dt}= Moisture content at t + dt (g water/g dry matter)

dt = Time between two sample weighing (min)

Results and Discussion

Drying kinetics of wood apple

Effect of air velocity and temperature on moisture reduction

The foam mat drying of wood apple pulp was continued from the initial moisture 566.66 % (d.b.) to the final moisture level of 10.10 to 6.48% (d.b) at various drying air temperature and ait velocity.

The initial moisture content of the 2 mm sample at 2 m/s air velocity was 566.67 per cent (d.b) and it took 240, 300 and 330 min to dry to a moisture content of 7.22 7.40, 7.96 per cent (d.b), at 65,60 and 55

°C temperature respectively. Similarly, for 2 mm sample at 2.5m/s air velocity it took 566.68 to 6.00,6.48, and 7.40 per cent (d.b) it took 200, 255, and 300 min. It was observed that for the samples of 2.5 m/s air velocity the moisture removal rate was faster when compared to 2m/s air velocityat varying temperature.

The relation of moisture change with respect to the required drying period of wood apple is given in (Figure 1), which clearly shows a non-linear continuous decrease in moisture with the drying period. The variation of drying air temperature has been found reflected in values of the drying period. The total drying period and the drying temperature are inversely proportional to each other; as the drying temperature decreases, the drying period is prolonged.

Effect of process variable on drying rate of foam mat drying of wood apple

The relationship between drying rate and moisture content is shown in Figures (2a) and (2b). From all the experiments it is clear that drying rate decreased with decrease in moisture content for all samples. During the initial stages of drying, the foamed puree had a high drying rate due to significant moisture loss and high moisture diffusion.

As drying progressed, the moisture content of the foamed material decreased, resulting in a reduced drying rate. Therefore, the drying curves for all different combinations show that most drying occurs during the falling rate period. The drying rate decreases with a decrease in moisture content, and few points of curves interacted unexpectedly. This was maybe due to variations in experiments (Kohli *et al.*, 2017)

The maximum drying rate 0.06432g-w/g-dm-min was observed initially pulp dried at2.5 m/s air velocityand at 65°C. From the figures it can be observed that the drying rates were large at the start of the drying process and gradually decreased as the moisture contents of the products decreased. It was also observed that the drying rates for different drying temperatures varied during initial 120-240 min, but as the drying continues the drying rates became constant for all temperatures. The increase in drying rates with an increase in temperatures might be due to high moisture diffusivity at higher temperatures.

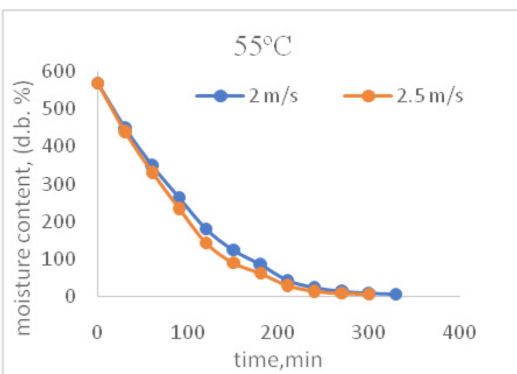

Fig. 1a.

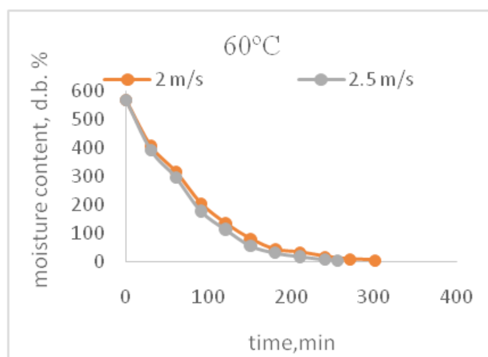

Fig. 1a.

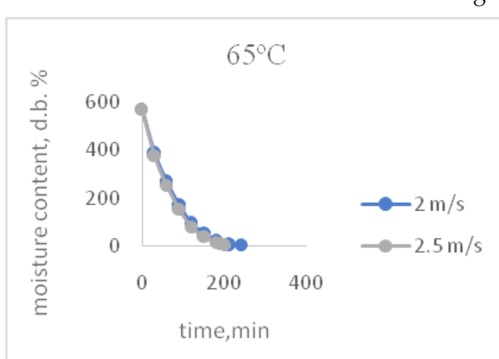

Fig. 1a.

Fig. 1. Moisture content versus drying time for wood apple pulp at different drying temperature and air velocity.

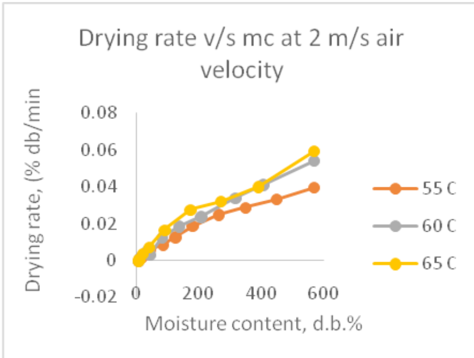

Fig. 2a

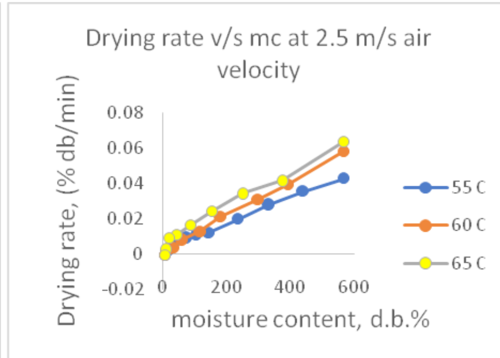

Fig. 2b

Fig. 2. Moisture content versus drying rate for wood apple pulp at different drying temperature and air velocity.

However, as drying continued, the rate slowed and stabilized because most of the free water was lost, leaving mainly bound water. These results are in line with the findings of several researchers worked on the drying characteristics of various fruits and vegetables like alphonso mango (Rajkumar *et al*., 2007), muskmelon (Asokapandian *et al.,* 2016), for drying of asparagus roots (Kohli *et al*., 2022) *etc.*

Effect of process variable on moisture ratio of foam mat dried wood apple

The variation of moisture ratio verses time for an experimental range of temperature (55-65 °C) and air velocity 2 m/s and 2.5 m/sis shown in Figures 3(a) and 3(b). The relationship of moisture ratio and time shows that there was a rapid decrease in moisture ratio with a faster rate at initial stage of 60 to 120 min of drying and in later stagesthe moisture ratio decrease in slower rate as moisture content approached to equilibrium moisture content. Moisture ratio curves for all the three levels of temperatures showed that the drying at 2.5 m/s, 65ºC was faster than other drying temperatures. It was also found that the drying rate was higher for higher air temperature and air velocity.

Conclusion

Foam mat drying of the underutilized fruit wood apple was conducted at three temperatures (55, 60, 65 ºC) and two air velocity. The drying kinetics of the foam mat dried wood apple pulp were influenced by both temperature and air velocity. The water activity, color, and rehydration ratio of wood apple powder are all influenced by drying temperature and air velocity. Foam mat drying not only reduces drying time but also maintains the quality of the product.

Conflict of Interest- None

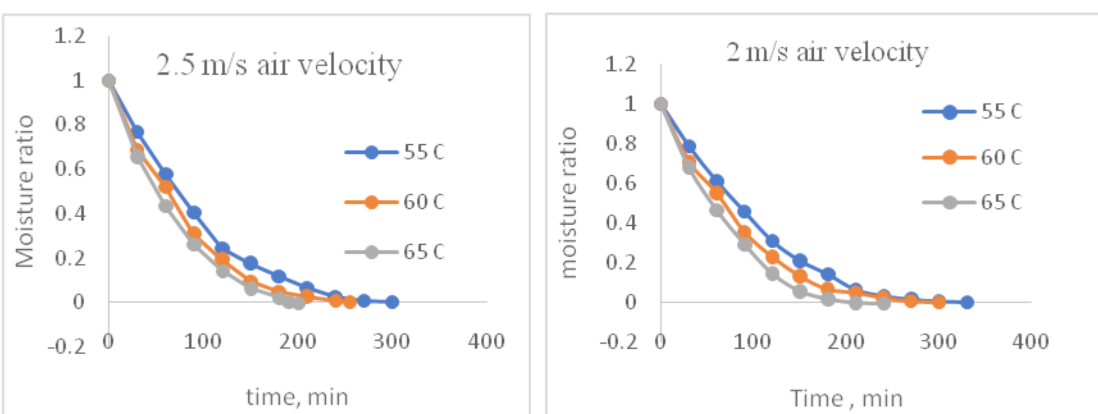

Fig. 3. Moisture ratio curves of the formulation at 55 °C (A), 60°C (B) and 65 °C (C) for different air velocity.

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