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Effect of vacuum assisted microwave drying on drying behavior of potato cubes

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ABSTRACT

The present study was focused on effect of microwave powers i.e. 160, 320, 480, 640, and 800 W on drying characteristics of potato cube (1.2 c. m. x 1.2 c. m. x 1.2 c. m.). Microwave drying led to reduction in moisture content and drying time reduced with the increase in power level. Increase in power level from 20% to 100% led to reduction in drying time approximately of 8 min. The drying rate increased with increasing power level having a minimum value of 0.043% for 160 W power levels to a maximum value of 0.29% for 800 W power levels. Increasing the vacuum level further increased the drying rate for each power level. At 160 W power level for 100 mmHg vacuum level the maximum reduction in moisture content was 48.668% dry basis, which was increased to a maximum difference in moisture content of 215.75% dry basis at 300 mmHg vacuum level or 800 W power level corresponding to a 1/8 time reduced duration of 2.5 min.

***Key words**: Microwave drying, Vacuum, Potato cube, Drying rate*

Introduction

The potato (*Solanum tuberosum*) is an important food crop of the solanaceae family commonly grown for its starchy tuber popularly known as 'The king of vegetables'. Potato is the third most important food crop in the world after rice and wheat which is consumed by more than a billion people worldwide. It is grown in about 155 countries throughout the world and India is the third largest country in world in production of potato after China followed by Russia. Potato is highly nutritious vegetable containing high energy, dietary fiber, biologically active phytochemicals, vitamins (particular vitamin C i.e. 14.0-25.0 mg per 100 g of fresh weight), and minerals (iron, calcium) which offer great benefit for use as functional food ingredient (Brinley *et al.,* 2008).

Drying is the oldest and most effective way for food preservation as it prevents the microbial and enzymatic reactions. It reduces the weight and volume of the product considerably which facilitate handling, transportation, packaging and storage (Kumar *et al.,* 2021). The most common methods widely used for drying are sun drying and hot air drying (Kumar *et al.,* 2021; Soysal, 2004). Although this is a simple process, the low thermal conductivity of food materials and internal resistance to moisture transfer yield that the efficiency of heat transfer is low and the quality of the dried fruits is generally reduced and often unsatisfactory. The main problem with hot air drying of fruit begins when the moisture content reaches to very low level the rate of moisture loss starts to decrease. Two-thirds of the drying time may be spent removing the last one-third of the moisture content in the final stage of drying. Because of their physical/chemical composition and structure (Zhang *et al.,* 2017), starch-rich fruits like bananas dry much more slowly than other

fruits. But prolonged drying times increase shrinkage and toughness, reduce the bulk density and rehydration capacity of the dried product and cause serious damage to the flavor, colour and nutrients (Srikanth *et al.,* 2021; Maskan, 2000). The effectiveness of a drying process depends on different factors: method of heat transfer, continuity or discontinuity of the process, direction of the heating fluids with respect to the product, pressure (atmospheric, low, deep vacuum) (Haghi *et al.,* 2008; Kumar *et al.,* 2021).

However, with respect to time different drying methods i.e. microwave drying, superheated steam drying, heat pump drying etc. has been developed. Among them microwave drying was found to be fast, economic and easy. Different studies have conducted on microwave drying of fruits and vegetables (Sorbus Fruits (Lüle and Koyuncu, 2015), cranberries (Zhou *et al.,* 2021), strawberries (Jiang *et al.,* 2021), vegetable soup (Wang *et al.,* 2010), Potatoes, savoy cabbage and white cabbage (Liburd *et al.,* 2019)). It was observed that the microwave drying is fast and reduces the drying time (Maskan, 2000; Decareau, 1985). The drying time can be reduced by using microwave energy, which is rapidly absorbed by the product water molecules and consequently results in rapid evaporation of water and thus higher drying rates. The interior temperature of dried microwave-heated food is higher than the surface temperature and moisture is transferred to the surface more dynamically than during convective drying (Pereira *et al.,* 2007). A combination of microwave drying and hot air drying creates a synergistic effect in terms of heating uniformity and brings significant advantages in regards to processing time and quality (Gowen *et al.,* 2008; Drouzas and Schubert, 1996). Different studies have been conducted on microwave drying of potato (Wang *et al.,* 2004; Bouraoui *et al.,* 1994; Luo *et al.,* 2018; Wang *et al.,* 2010 etc.) whereas Limited studies have been focused on microwave vacuum drying hence the present study was focused on effect of microwave drying and vacuum on drying characteristic of potato cubes.

Materials and Methods

Sample preparation

Potato samples for the present study were collected from local market of Jabalpur. Samples were cleaned and peeled, cut into the cubs of 1.2 cm for drying. The initial moisture content of potato cubes were (85% w.b.) determined using the hot air oven using the method of Vishkarma *et al.* (2015).

Microwave drying

Microwave drying was performed in domestic digital microwave oven (Bajaj ET-B 2300, 230 V, 50 Hz). The fresh potato cubes were placed in microwave oven for drying at five different power level i.e. 160, 320, 480, 640 and 800 for drying time durations varied from 0.5 min to 20 min depending upon power level and moisture loss from the product. The vacuum oven (Scientific Engineering Corporation Laboratory Instrument, Delhi.) was used as a vacuum chamber to expose the microwave dried potato cubes at vacuum levels of 100, 150, 200, 250 and 300 mmHg below atmospheric pressure. Microwave drying was carried out for different time and after each interval, dried potato cubes were kept for vacuum tempering in vacuum oven used as vacuum chamber for five minutes. Moisture loss was determined by weighing on the sample using digital balance (Plate-3.2) with 0.01 g precision.

Drying Kinetics Analysis

Drying Rate (DR)

Drying rate (g of water per minute per 100 g of bone dry material) was calculated using the method described by Vishkarma *et al.* (2015).

$$\text{Drying rate} = \frac{\text{Amount of moisture removed (g)}}{\text{Time taken (t) (min)} \times \{\text{Total bone dry weight of sample (Wd) g/100 g)}} \quad \text{.. (1)}$$

Similarly, the drying rate will be approximately proportional to the difference in moisture content between the product being dried and EMC at the drying air state:

$$DR = \frac{M_{t+dt} - Mt}{dt} \quad \text{.. (2)}$$

Where, DR = drying rate (g/g min), M_t = moisture content at time t (%db), M_{t+dt} = moisture content at time t+dt (%db), d_t= time of successive measurements (min)

Statistical analysis

All the experiments were performed in triplicate and data were presented in mean ± SD. Coefficient of determination R^2 was calculated for the predic-

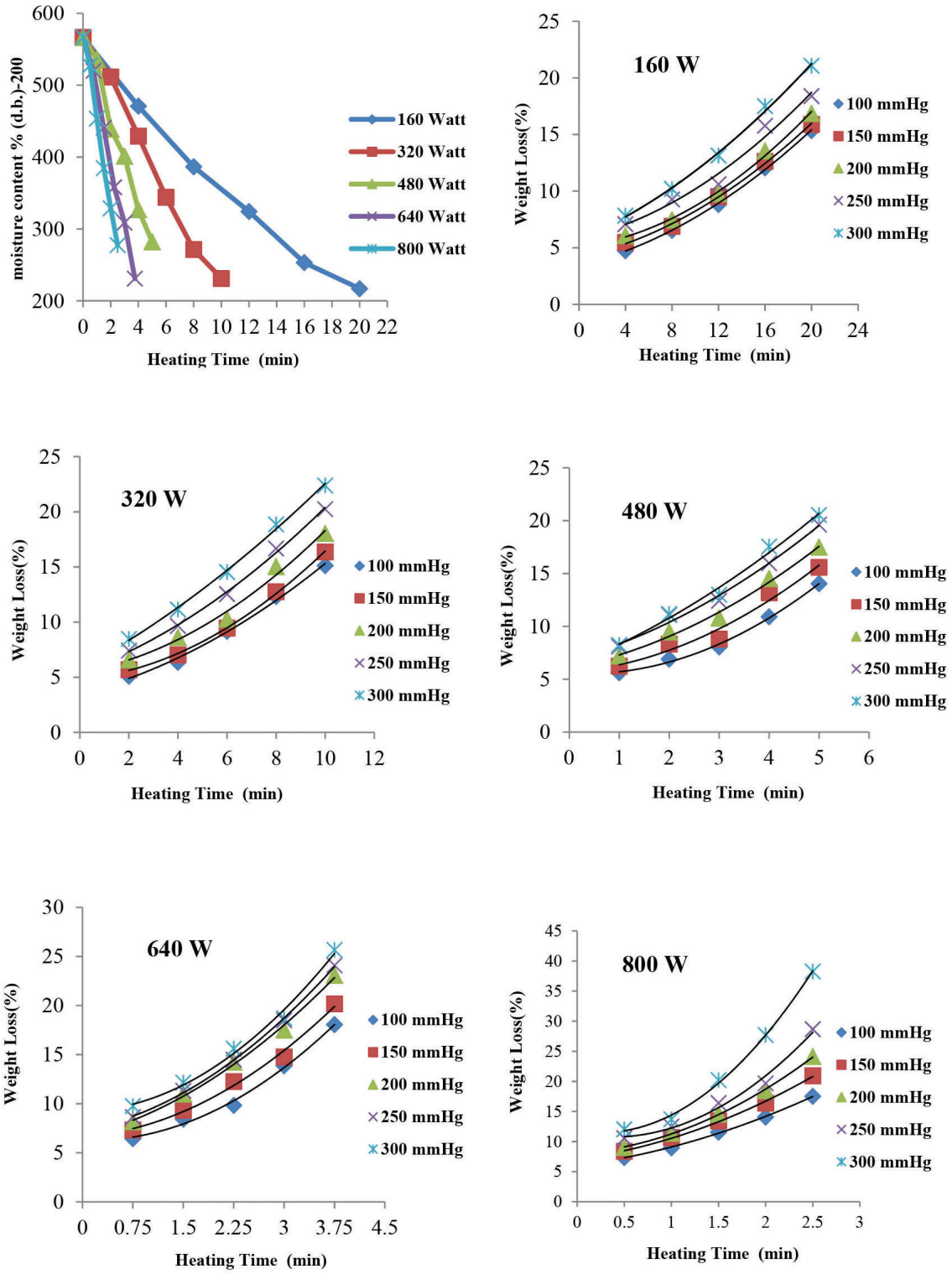


Fig. 1. Effect of microwave drying and vacuum level of moisture content and weight loss of potato cubes.

tion of future outcomes on the basis of other related information.

Results and Discussions

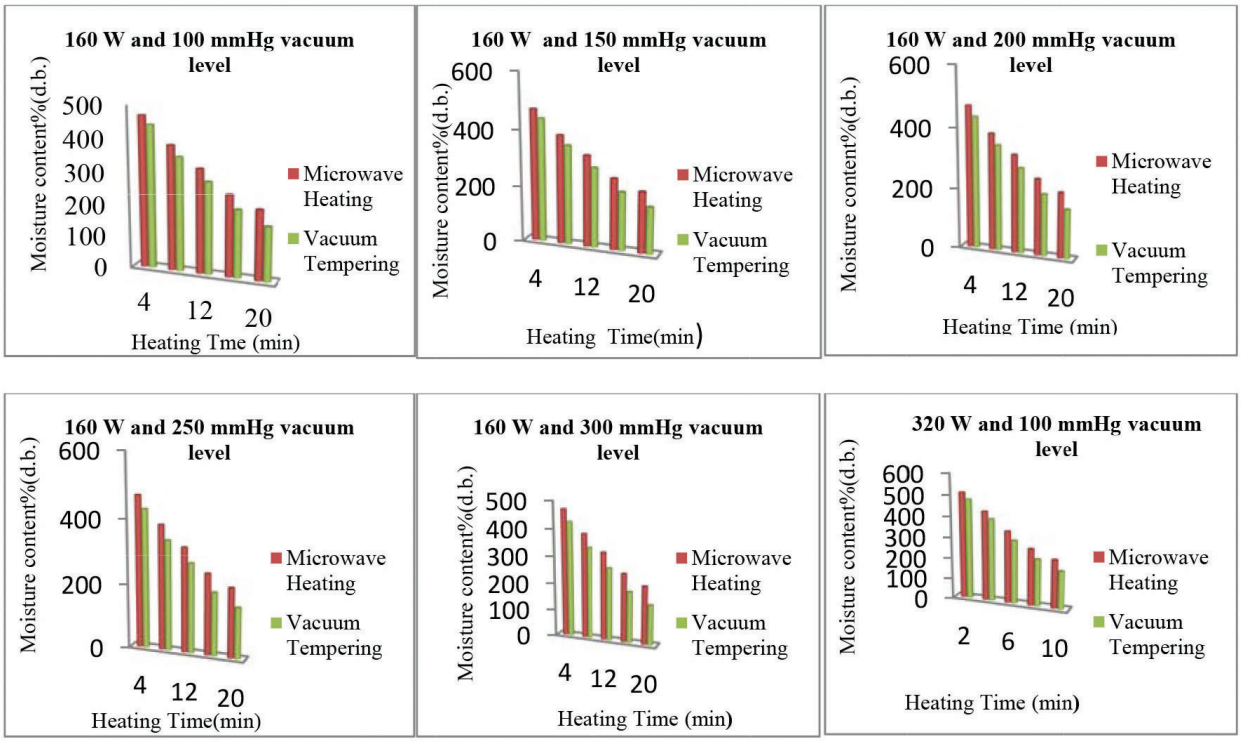
Effect of microwave power on drying Characteristics

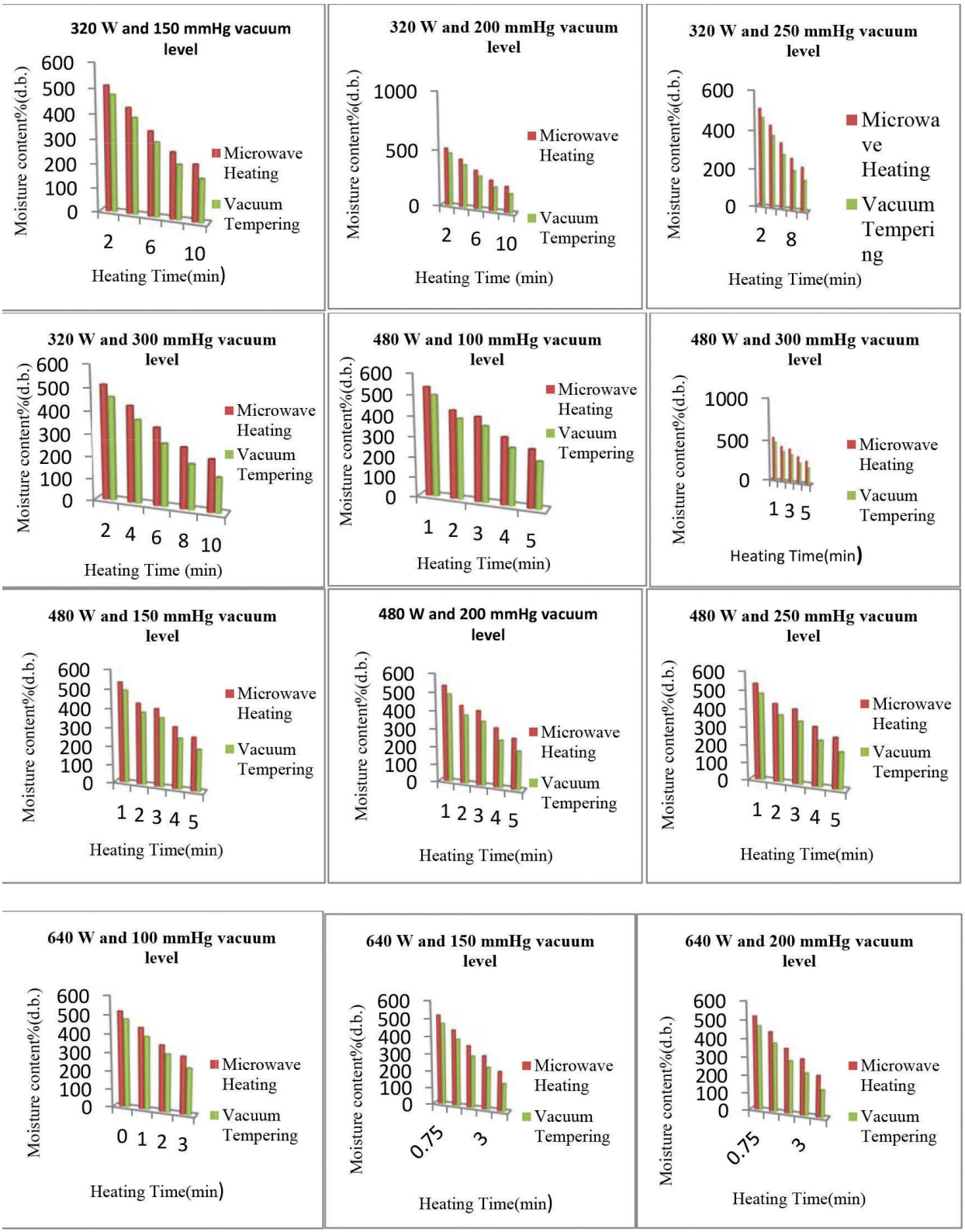
Moisture depletion of potato cubes as affected by heating power level and time (Fig. 1). A reduction in drying time occurred with the increasing microwave power level. The microwave heating process reduced the moisture content of potato cubes from 566.6667% (d.b.) to 216.9934% (d.b.), depending on microwave power levels and heating time. By working at 100% power level, instead of 20% power level, the drying time was shortened. A marked decline was noted in the drying period of potato cubes with the increasing microwave power level (Drouzas and Schubert, 1996; Prabhanjan *et al.*, 1995; Soysal, 2004). During the drying of potato cubes at 5 different microwave power, a total of 0.65(±0.01) g/min at 20% power level, 1.25 (±0.02)g/min at 40% power level, 2.13 (0.03)g/min at 60% power level, 3.33 (±0.04) g/min at 80% power level and 5.16 (±0.5) g/min at 100% power level, weight loss occurred from each drying sample depending upon the heating time and microwave power level. The quantity of moisture removed from the material was increased in every min of drying cycle and also with increase in microwave power levels. Maximum value of moisture removed from the material at 100% microwave power level obtained was 5.16 g/min, Minimum value of moisture removed from the sample was 0.65 g/min at 20% microwave power level.

Effect of vacuum on drying behavior

The rate of moisture removal was obtained in unit time under constant microwave power levels and different vacuum levels are given in Fig. 2. At 160 watt constant power level as we increases the vacuum level in vacuum tempering removal of moisture increase with vacuum level. At 160 watt 4 min microwave heating 100 mmHg vacuum level weight loss was 4.733% and At 160 watt 20 min microwave heating 100 mmHg vacuum level weight loss was 15.353%, At 160 watt 4 min microwave heating 300 mmHg vacuum level weight loss was 7.83% and At 160 watt 20 min microwave heating 300 mmHg vacuum level weight loss was 21.07%because as we increase the microwave heating time moisture removal was increased in vacuum tempering.

The moisture content reduction in microwave were 470.91 and 216.993%(d.b.) and in vacuum tem-




320 W and 150 mmHg vacuum level
Moisture content%(d.b.)
600
500
400
300
200
100
0
2 6 10
Heating Time(min)
Microwave Heating
Vacuum Tempering
320 W and 200 mmHg vacuum level
Moisture content%(d.b.)
1000
500
0
2 6 10
Heating Time (min)
Microwave Heating
Vacuum Tempering
320 W and 250 mmHg vacuum level
Moisture content%(d.b.)
600
400
200
0
2 8
Heating Time(min)
Microwave Heating
Vacuum Tempering
320 W and 300 mmHg vacuum level
Moisture content%(d.b.)
600
500
400
300
200
100
0
2 4 6 8 10
Heating Time (min)
Microwave Heating
Vacuum Tempering
480 W and 100 mmHg vacuum level
Moisture content%(d.b.)
600
500
400
300
200
100
0
1 2 3 4 5
Heating Time(min)
Microwave Heating
Vacuum Tempering
480 W and 300 mmHg vacuum level
Moisture content%(d.b.)
1000
500
0
1 3 5
Heating Time(min)
Microwave Heating
Vacuum Tempering
480 W and 150 mmHg vacuum level
Moisture content%(d.b.)
600
500
400
300
200
100
0
1 2 3 4 5
Heating Time(min)
Microwave Heating
Vacuum Tempering
480 W and 200 mmHg vacuum level
Moisture content%(d.b.)
600
500
400
300
200
100
0
1 2 3 4 5
Heating Time(min)
Microwave Heating
Vacuum Tempering
480 W and 250 mmHg vacuum level
Moisture content%(d.b.)
600
500
400
300
200
100
0
1 2 3 4 5
Heating Time(min)
Microwave Heating
Vacuum Tempering
640 W and 100 mmHg vacuum level
Moisture content%(d.b.)
600
500
400
300
200
100
0
0 1 2 3
Heating Time(min)
Microwave Heating
Vacuum Tempering
640 W and 150 mmHg vacuum level
Moisture content%(d.b.)
600
500
400
300
200
100
0
0.75 3
Heating Time(min)
Microwave Heating
Vacuum Tempering
640 W and 200 mmHg vacuum level
Moisture content%(d.b.)
600
500
400
300
200
100
0
0.75 3
Heating Time(min)
Microwave Heating
Vacuum Tempering

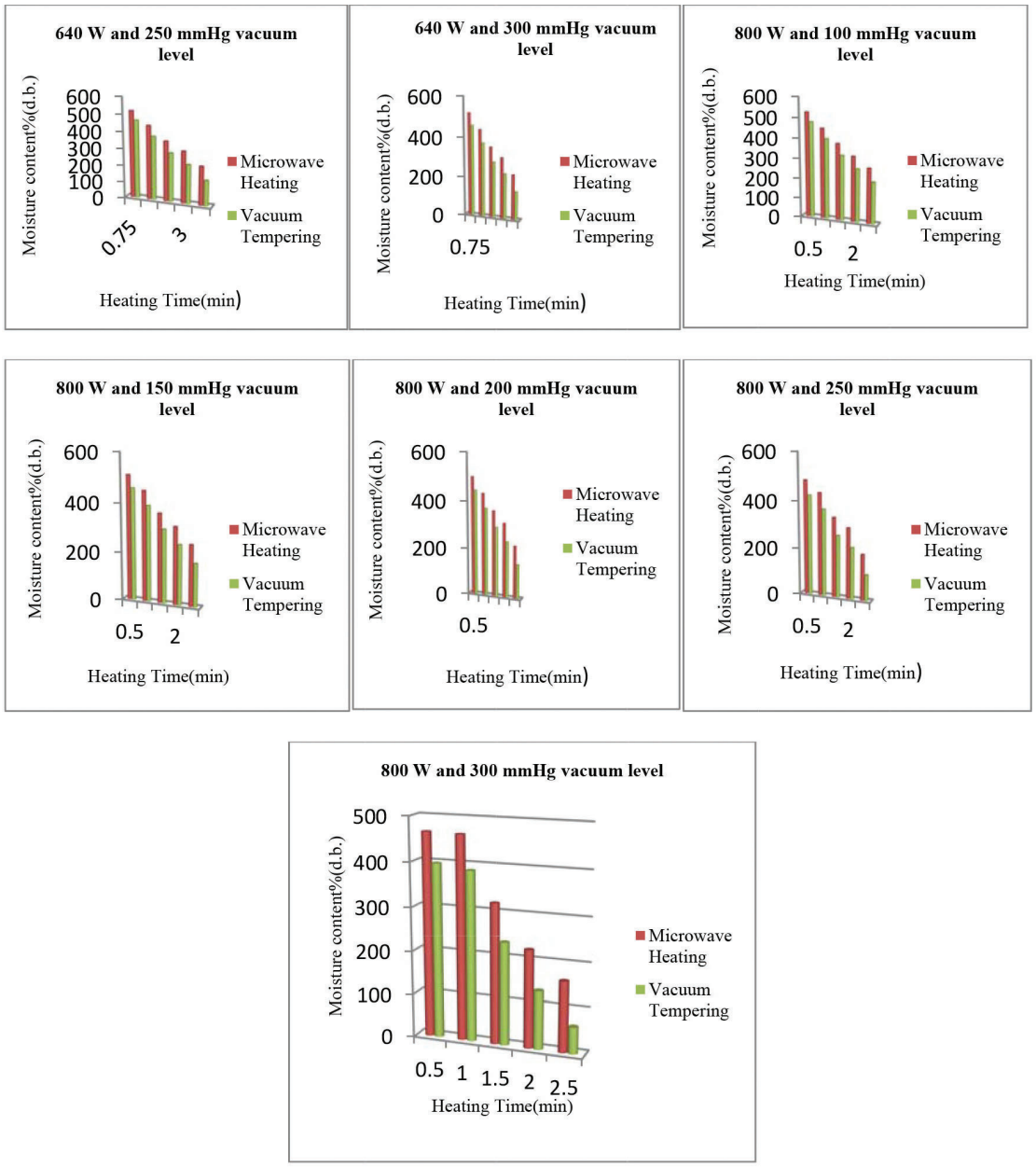


Fig. 2. Comparative analysis of microwave power and vacuum on moisture content of potato cubes.

pering were 443.89 and 168.325% (d.b.) with respect to heating time 4 and 20 min. respectively. Fig.2 shows that the moisture content reduction was less in microwave heating as compared to vacuum tempering. At 320 watt constant power level as we increases the vacuum level in vacuum tempering removal of moisture increases with vacuum level. At 320 watt 2 min microwave heating 100 mmHg vacuum level weight loss was 5.08% whereas at 800 watt 2.5 min microwave heating 300 mmHg vacuum level weight loss was 38.26%because as we increases the microwave heating time moisture removal was increased in vacuum tempering. Vacuum led to increase in moisture removal might be due to the increase in driving force by creating the pressure different.

Conclusions

Present study was concluded that the microwave

drying and associated vacuum led to reduction in drying time. Moisture content of potato cubes decreases with increase in drying time and the rate of removal of moisture increases with increasing power level. At 100% power level as compared to 20% power level the drying time was shortened by 8 min for386.56% moisture content on dry basis and 16 min on 384.56% moisture content on dry basis removal of moisture content. Drying rate increased with increasing power level having a minimum value of 0.043% for 160 watt power level to a maximum value of 0.29% for 800 watt power level. Increasing the vacuum level always yields increased reduction in moisture content for a given heating time at a given power level. At 160 watt power level for 100 mmHg vacuum level the maximum reduction in moisture content was 45.66% d.b. ,which was increased to a maximum difference in moisture content of 215.76% d. b. at 300 mmHg vacuum level or 800 watt power level corresponding to a 1/8 times reduced duration of 2.5 minute.

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Conflict of interest:- Authors do not have known conflict of interest.

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