Effect of Variable Microwave Power and Vacuum Levels during Dehydration on the Quality Attributes of Potato Cubes

OP Chauhan1*, Bhawya D1, Manoranjan Kumar1, N Roopa1, and PS Raju1

Received 11 March 2015; Published online 25 July 2015

© The author(s) 2015. Published with open access at www.uscip.us

Abstract

Potato cubes were dehydrated at different microwave power (200-600 W) levels with or without application of vacuum (ranging from 150 to 450 mbar) and were compared with those dehydrated under hot air drying conditions at 60°C in terms of dehydration rate, bulk density and rehydration ratio as well as CIE colour values (L*, a*, b*), textural and microstructural quality. Drying rate was found to be higher at higher microwave power levels and application of vacuum further increased the drying rate. The lowest bulk density (0.23 g/cc) and highest rehydration ratio (5.26) as well as CIE L* value (66.72) was recorded in the sample dehydrated under high vacuum (150 mbar) and 600 W microwave power. The cubes dehydrated at 400 W under vacuum (150 mbar) showed minimum hardness (7.93 N) and first fracture (3.25 N) values. Texture profile analysis of rehydrated cubes revealed maximum hardness (3.94 N) in the case of samples dehydrated at 400 W without vacuum, whereas those dehydrated at 400 W and 150 mbar vacuum showed minimum hardness (1.50 N) and springiness values (1.02) after rehydration. Highest sensory scores for overall acceptability were recorded for the cubes dehydrated at 600 W microwave power under vacuum (150 mbar). Scanning electron microscope studies also revealed better textural retention in vacuum-assisted microwave dehydrated compared to those dehydrated using microwaves without vacuum or cabinet dehydrated ones.

Keywords: Microwave; Dehydration; Vacuum; Potato; Quality; Rehydration

1. Introduction

Application of microwaves is relatively a new for dehydration of foods. It is a rapid dehydration method that can be applied to specific foods, particularly to fruits and vegetables. Microwaves have been used as a heating source since 1940s and its application has extensively been employed in food and chemical engineering industries (Figiel, 2009). The advantages of microwave dehydration
include shorter drying time, improved product quality and flexibility in producing a wide variety of
dried products. Microwave drying characteristics are affected by many factors including type of
food, dielectric properties, microwave power and product geometry. Non-uniform heating of the
food products is often organized as shortcoming in microwave heating. In general, this is caused by
the non-uniform microwave distribution within a microwave oven and different rates of microwave
power of absorption by the various food components (Kassem et al., 2011).

Potato is an important vegetable and is generally consumed worldwide in the form of curries, chips,
French fries, boiled potatoes, etc. Dehydration is often used to process potato but generally produces an
inferior quality product. The fresh cut/sliced potatoes also undergoes browning having impact on
final product and high temperature and long term drying involved in conventional hot air dryers
can cause serious damage to product colour and reduce rehydration capacity of dried product
(Wang et al., 2010). The disadvantage of hot air drying also includes loss in the product quality,
such as colour, nutrient concentration, flavor and texture (Gowen et al., 2008). Microwave drying
has the advantage of selective heating energy efficiency speed and requirement of less floor space
(Schiffmann, 2001). Microwave energy can be successfully applied in several processes in the food
industry because the resulting volumetric heating of the material results in a slower transfer of heat
from the surface to the interior surface compared to convective drying. This phenomenon is related
to the energy converted into kinetic energy of water molecules and then into heat when the water
molecules realign in the changing electrical field and interact with the surrounding molecule
(friction) (Khraisheh et al., 1997). The microwave drying technique has been used for drying
carrots (Sumnu et al., 2005), mushrooms (Lombrana et al., 2010), apples (Botha et al., 2012), etc.
One of the advances in microwave drying is the application of vacuum, a novel alternative method
which ensures shorter drying time and a substantial improvement in the quality of dried materials
in relation with those dried with hot air and microwave drying methods. Better quality of cranberries dried using vacuum microwave and microwave hot-air techniques have also been
reported (Sunjka et al., 2004). Botha et al. (2012) reported that if microwave drying applied
improperly, results in a poor quality product. Therefore, the present investigation was envisaged to
study the quality of potato cubes dried at different combinations of microwave power and vacuum
levels and to compare the product characteristics with hot air dried ones.

2. Material and Methods

Raw material and pretreatment

Fresh potatoes were procured from local market of Mysore, India having initial moisture content of
82-85% (wet basis) and were sorted visually for uniform size, colour, firmness, and absence of
physical damages. Prior to drying, the potatoes were washed, peeled and cut into halves and then
uniformly cut into cubes (1x1x1cm) using a mechanical dicer (Urschel Laboratory Inc., Valparaiso,
USA) and blanched in boiling water (1:2, w/v) containing 1000 mg.kg\(^{-1}\) potassium-meta-bisulfite for
two minutes followed by draining and then subjected for drying experiments.

Microwave dehydration

The drying experiments were performed in a specially designed vacuum assisted microwave
dehydration unit (Model PTF 2712, Energy Microwave System, Bangalore, India) at a frequency of 2450MHz. The unit has the facility for manual power (0-1000 W) and vacuum (100-1000 mbar) settings. Cooling of magnetron and transformer was given prime consideration while designing the microwave dehydration unit for maintaining the constant power output which was achieved by the introduction of an electric fan. Microwave dehydration of the samples were performed at 200, 400 and 600 W microwave power and 150, 300, 450 mbar vacuum levels. For each experiment, 100 g of samples were placed in the microwave oven and weight loss was recorded at specific time intervals till final moisture content of about 6-7% (wet basis) was achieved. The potato cubes were also dehydrated under microwave without application of vacuum. The rotation speed of the turntable was 5 rpm. All the measurements were taken within 1 min. The moisture of the dried sample at the end of every drying period was calculated according to the loss of weight and value of initial moisture content. The sensible heat loss due to the above interruptions compared to evaporation heat was small and could be neglected. Three replicates were carried out for each set of experiment and the mean value and standard error in moisture content at each experimental point were calculated.

**Hot air dehydration**

The hot air dehydration experiment were performed in a cabinet drier (Kilburn, Macneill and Magor Ltd., Kolkata, India) drying was performed at 60°C with an air velocity of 1.5±0.1 m/s. 100g of sample were placed in the drier and in every 30 min weight loss was recorded and moisture content was determined based on g/g solids (dry basis).

**Moisture estimation**

The moisture content was determined by drying in a vacuum oven at 60°C until constant weight was achieved as described by Ranganna (1999).

**Rehydration ratio and bulk density**

Rehydration ratio and bulk density were determined by using the method as prescribed by Ranganna (1999). The rehydration capacity of dried potato cubes were evaluated by immersing 1g of sample in boiling water for 20 minutes. Then the samples were taken out followed by surface moisture removal using towel paper and then weighed. The rehydration ratio was calculated from sample weight before and after rehydration.

\[
\text{Rehydration ratio} = \frac{W_r}{W_d} \tag{1}
\]

where,

\[
W_r = \text{Weight of rehydrated sample (g)}
\]

\[
W_d = \text{Weight of dried sample}
\]

Bulk density was calculated as per the equation given below which is the weight of dehydrated sample by its respective volume and is reported as g/cc.

\[
\text{Bulk density} = \frac{W_1}{W_2} \tag{2}
\]

where,
\[ W_1 = \text{Weight of dehydrated sample} \]
\[ W_2 = \text{Volume of the dehydrated sample (measured using graduated cylinder)} \]

**Colour measurements**

The CIE (Commission Internationale de l'Eclairage) colour values (\(L^*, a^*, b^*\)) were measured using D-65 illuminant and 10° observer using a colour meter (MiniScan XE Plus, Model No. 45/0-S, Hunter Associates Laboratory, Inc., Reston, VA, USA). Standard white and black tiles were used as a reference. Triplicate readings were carried out for each sample and average of the same has been reported.

**Texture analysis**

Hardness and texture profile analysis was carried out with a texture analyzer (TAHDi, Stable Micro Systems Ltd. London, UK) using a 25 kg load cell and the data were recorded with a computer supported with software (Texture Expert, Version 1.22, Stable Micro Systems Ltd. London, UK). The data were recorded in triplicate and mean values were considered for computing the final results. Texture profile analysis of fresh and rehydrated potato cubes was carried out using a 75 mm compression plate up to 25% strain at a speed of 1mm/s with automatic return. The pre-test and post-test speeds were set at 2mm/s, respectively. The software automatically calculated for textural parameters viz. chewiness, cohesiveness and springiness. Hardness of the dehydrated cubes was measured using the same compression plate at a test speed of 1mm/s and first fracture and peak hardness values were calculated.

**Sensory acceptability**

The potato cubes were subjected for sensory acceptability after dehydration as well as rehydration. The dehydrated as well as rehydrated samples were subjected to a panel of 30 members for judging overall sensory acceptability based on visual appearance, color and texture of the cubes on a 9-point hedonic scale; 9 indicating highly acceptable and 1 as least acceptable (Lawless and Heymann, 1998).

**Microstructural analysis**

Microstructural analysis of dehydrated potato cubes were carried out using a scanning electron microscope (Quanta 400, Environmental SEM, FEI Company, USA). The dehydrated samples were critical point dried (CPD) using liquid carbon dioxide. The samples specimens were mounted on brass stubs using double sided adhesive tapes and gold coated in an ion sputter coating unit (JEOL JFC 1100, Tokyo, Japan) for 10 min under low vacuum with argon gas to provide a reflective surface for the electron beam. An acceleration potential of 20kV was used during micrography and images magnified at 500x.

**Statistical analysis**

The data obtained after various analysis were analyzed statistically using analysis of variance (ANOVA) technique to determine significant differences among various treatments at \(P<0.05\)
significance level using Statistica 7 software (StatSoft, Tulsa, OK, USA).

3. Results and Discussion

Dehydration characteristics

The dehydration curves for potato cubes under different drying conditions have been shown in Fig. 1(a-e). The moisture content decreased exponentially with drying time in all the experimental conditions. It has been reported that almost all of the drying of biological materials takes place in the falling rate period (Wang et al., 2007). The drying curves of potato cubes subjected to vacuum-assisted and microwave drying showed that higher microwave power led to increased rates of evaporation and moisture loss with drastic reduction in drying time (Table 1). It took much longer time under hot air dehydration as compared to microwave or vacuum-assisted microwave dehydration. In the case of microwave dehydration also, drying time was comparably different for different power levels. When microwave heating was combined with vacuum, it was possible to dry potato cubes faster as compared to microwave dehydration alone. Drying time in vacuum-assisted microwave combination was quiet reduced as compared to drying time in microwave only. Time required to reduce initial moisture content of potato cubes from around 85% to about 5% under microwave drying conditions at the highest power and vacuum (600W/150mbar) was 30 min while it was 90 min in microwave drying at low power and vacuum (200W/450mbar) level.

The drying time was found to be 360 min under hot-air drying condition. Thus, the drying time was much shorter in vacuum-assisted microwave drying than that of hot air drying. Shorter drying time in microwave drying can be explained by higher uniform internal temperature due to dipole frictional heat throughout the sample leading to faster moisture loss under vacuum condition. Cui et al. (2004) also reported that microwave power and vacuum pressure affects the drying rate and for constant vacuum pressure, the drying rate was found to be the first order of microwave power output. The bulk density was found to be maximum (0.83 g/cc) in the sample dehydrated under hot air drying condition, whereas, minimum (0.23 g/cc) bulk density was recorded in the sample dehydrated at 600 W microwave power and 150 mbar vacuum (Table 1).

The bulk density was found to decrease with increase in the level of vacuum suggesting puffed nature of the products. Rehydration ratio is a complex process and indicates the chemical and physical changes caused by drying procedures (Feng and Tang, 1998; Lewicki, 1998), and is widely used as a quality evaluation method after drying. The rehydration ratio of potato cubes dried by vacuum assisted microwave drying/microwave drying was found to be significantly ($P<0.05$) different from that of hot-air dried potato cubes indicating a 3-4 fold recovery of dried weight (Table 1). This property may be due to the high internal pressure produced by microwave heating which can cause structure of potato cubes to expand and puff. Less dense structure had higher capacity to absorb water upon reconstitution. Lower rehydration values of hot-air dried potato cubes can be evidence for product shrinkage caused by heating for prolonged time resulting in irreversible chemical and physical changes such as case hardening and leading to higher bulk density. The vacuum used during microwave dehydration further improved the puffiness of the dehydrated cubes making the product lighter with low bulk density values. The rehydration of the cubes showed increasing order in the samples dried at low to higher vacuum conditions.
Fig. 1. Dehydration curve for potato cubes under different drying conditions; (a) microwave without vacuum, (b) with variable vacuum at 200W, (c) with variable vacuum at 400W, (d) with variable vacuum at 600W, and (e) cabinet drying at 60°C.
Table 1: Drying characteristics of dehydrated potato cubes (n=3)

<table>
<thead>
<tr>
<th>Microwave Power (W)</th>
<th>Vacuum (mbar)</th>
<th>Bulk Density (g/cc)</th>
<th>Rehydration ratio</th>
<th>Drying time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>0</td>
<td>0.51±0.02</td>
<td>2.82±0.02</td>
<td>95±2</td>
</tr>
<tr>
<td>150</td>
<td>0</td>
<td>0.42±0.01</td>
<td>3.75±0.02</td>
<td>75±3</td>
</tr>
<tr>
<td>300</td>
<td>0</td>
<td>0.43±0.02</td>
<td>3.64±0.02</td>
<td>85±2</td>
</tr>
<tr>
<td>450</td>
<td>0</td>
<td>0.45±0.02</td>
<td>3.40±0.03</td>
<td>90±2</td>
</tr>
<tr>
<td>400</td>
<td>150</td>
<td>0.45±0.02</td>
<td>2.83±0.02</td>
<td>70±3</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>0.25±0.01</td>
<td>4.64±0.03</td>
<td>45±3</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>0.27±0.02</td>
<td>4.43±0.03</td>
<td>55±3</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>0.30±0.01</td>
<td>4.04±0.03</td>
<td>65±4</td>
</tr>
<tr>
<td>300</td>
<td>0</td>
<td>0.45±0.01</td>
<td>4.10±0.01</td>
<td>60±3</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>0.23±0.02</td>
<td>5.26±0.02</td>
<td>30±2</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>0.27±0.02</td>
<td>4.71±0.02</td>
<td>35±2</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>0.25±0.02</td>
<td>4.08±0.02</td>
<td>40±3</td>
</tr>
<tr>
<td>Hot air drying</td>
<td>0</td>
<td>0.83±0.04</td>
<td>2.44±0.02</td>
<td>360±4</td>
</tr>
<tr>
<td>CD (P&lt;0.05)</td>
<td></td>
<td>0.007</td>
<td>0.072</td>
<td>3.400</td>
</tr>
<tr>
<td>SEM (±)</td>
<td></td>
<td>0.002</td>
<td>0.024</td>
<td>1.169</td>
</tr>
<tr>
<td>F value</td>
<td></td>
<td>**</td>
<td>**</td>
<td></td>
</tr>
</tbody>
</table>

**Significant (P<0.05)

Shrinkage during drying has been found to not only affecting the product quality but also rehydration capability of the dried food material (Maskan, 2001). The shrinkage has also been found to be more severe at higher vacuum pressures which could be explained by the fact that when water is removed from the material during drying, a pressure unbalance is generated between the interior of the dried material and the external environment, which in turn induces the contracting stresses that lead to shrinkage (Wu et al., 2007).

CIE colour values

Table 2 shows the CIE color values of the dehydrated potato cubes. The lightness (L*) and greenness (a*) of potato cubes increased after blanching, whereas, yellowness (b*) of the cubes decreased. Drying also caused increased in the lightness of the products. The L* values of potato cubes also increased with increase in microwave power level which indicating higher microwave power yielded lighter colour in the dehydrated samples. Reports also exist with regards to microwave drying and microwave vacuum drying preventing colour damages during drying (Krokida and Maroulis, 1999). Hot air dried potato cubes were significantly (P<0.05) darker in colour compared to potatoes dried at high and medium powers of microwaves with or without application of vacuum. This was probably due to shorter drying time in the case of microwave drying.
dehydration. Similar results have also been reported by Maskan (2000) in the case of banana slices. The $b^*$ values were also found to be higher in the samples dehydrated under vacuum assisted microwave conditions. Hot air dried potato cubes were found to be darker with less yellow and red hues as compared to microwave dried ones which may be attributed to the short period of drying in microwave under vacuum condition (Lin et al., 1998). The lower $b^*$ value in hot air dehydrated samples was primarily due to the combined effect of oxygen and temperature which in turn have enhanced the formation of maillard reaction triggering with the result of a lower color in hot air dehydrated samples. Sumnu et al. (2005) also reported increase in L* values with increase in the microwave power level due to shorter drying time at higher power levels.

Table 2 CIE colour values of dehydrated potato cubes (n=3)

<table>
<thead>
<tr>
<th>Microwave Power (W)</th>
<th>Vacuum (mbar)</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>-</td>
<td>45.09±0.02</td>
<td>-0.17±0.01</td>
<td>7.65±0.06</td>
</tr>
<tr>
<td>Blanched</td>
<td>-</td>
<td>47.64±0.03</td>
<td>-2.72±0.02</td>
<td>-1.29±0.08</td>
</tr>
<tr>
<td>200</td>
<td>0</td>
<td>65.46±0.02</td>
<td>-3.31±0.02</td>
<td>2.44±0.04</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>54.44±0.04</td>
<td>-1.98±0.01</td>
<td>11.37±0.06</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>61.53±0.03</td>
<td>-2.93±0.01</td>
<td>-0.38±0.05</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>61.46±0.03</td>
<td>-1.48±0.03</td>
<td>12.68±0.04</td>
</tr>
<tr>
<td>400</td>
<td>0</td>
<td>58.30±0.01</td>
<td>-1.25±0.02</td>
<td>8.95±0.06</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>53.29±0.02</td>
<td>-2.70±0.01</td>
<td>-2.80±0.07</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>56.61±0.02</td>
<td>-2.53±0.01</td>
<td>-0.08±0.02</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>61.99±0.01</td>
<td>-2.15±0.01</td>
<td>3.15±0.03</td>
</tr>
<tr>
<td>600</td>
<td>0</td>
<td>60.06±0.02</td>
<td>-2.63±0.02</td>
<td>6.58±0.05</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>66.72±0.03</td>
<td>-2.52±0.01</td>
<td>1.72±0.05</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>60.20±0.04</td>
<td>-2.92±0.02</td>
<td>3.02±0.06</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>62.25±0.03</td>
<td>-2.92±0.02</td>
<td>3.93±0.04</td>
</tr>
<tr>
<td>Hot air drying</td>
<td>0</td>
<td>56.83±0.03</td>
<td>-2.08±0.02</td>
<td>4.67±0.03</td>
</tr>
<tr>
<td>CD ($P&lt;0.05$)</td>
<td></td>
<td>1.126</td>
<td>0.007</td>
<td>0.455</td>
</tr>
<tr>
<td>SEM (±)</td>
<td></td>
<td>0.389</td>
<td>0.002</td>
<td>0.157</td>
</tr>
<tr>
<td>F value</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant ($P<0.05$)

Textural characteristics

Peak hardness and first fracture point were calculated from the curves obtained from textural analysis. Microwave dehydrated potato samples showed significantly ($P<0.05$) lower hardness and first fracture values as compared to cabinet dehydrated one indicating softer nature of the product.
Maximum hardness was observed in the samples dehydrated under hot air drying conditions, whereas, minimum hardness was recorded in the samples dehydrated at 400 W and 150 mbar vacuum. In the case of microwave dehydration, faster drying happened ultimately leading to puffed and crisp products. Inclusion of vacuum during microwave dehydration further facilitated the generation of porous structure during drying. This fact is common in microwave dehydrated products (Bondaruk et al., 2007) due to the fast water evaporation which takes place in the fruit/vegetable matrix softened by thermal effects. The highest hardness in the case of hot air dried product can be related to case hardening effect that implies a harder external layer in the dried product (Contreras et al., 2005). Hot air drying caused shrinkage of the potato cubes leading to case hardening. The mechanical response of dried samples is the result of behavior of cellular matrix and soluble solid phase inside the tissue having different interactions with water. Changes in cell walls as well as water soluble fractions cause differences in mechanical behavior of the tissue, depending on the water content. Texture profile analysis of rehydrated cubes revealed maximum hardness (3.94 N) and chewiness (1.41) was recorded in the sample dehydrated at 400 W without vacuum, whereas those dehydrated at 400 W and 150 mbar vacuum showed minimum hardness (1.50 N) after rehydration. Cohesiveness was found to be maximum in the samples dehydrated at 600 W and 150 mbar vacuum. The hot air dehydrated sample showed maximum (2.97) springiness values after rehydration. The values for hardness in rehydrated cubes were found to be significantly ($P<0.05$) lower as compared to fresh and blanched ones (Table 4).

**Table 3** Hardness and first fracture point of dehydrated potato cubes (n=3)

<table>
<thead>
<tr>
<th>Microwave Power (W)</th>
<th>Vacuum (mbar)</th>
<th>First fracture (N)</th>
<th>Hardness (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>0</td>
<td>30.12±0.08</td>
<td>113.4±0.05</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>6.14±0.07</td>
<td>39.77±0.05</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>11.96±0.05</td>
<td>14.67±0.06</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>9.12±0.04</td>
<td>19.34±0.04</td>
</tr>
<tr>
<td>400</td>
<td>0</td>
<td>20.93±0.05</td>
<td>80.28±0.02</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>3.25±0.06</td>
<td>7.93±0.02</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>12.58±0.05</td>
<td>19.43±0.03</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>6.21±0.07</td>
<td>35.3±0.08</td>
</tr>
<tr>
<td>600</td>
<td>0</td>
<td>7.72±0.05</td>
<td>46.57±0.05</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>5.21±0.06</td>
<td>15.03±0.05</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>16.45±0.06</td>
<td>26.54±0.04</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>6.57±0.02</td>
<td>8.62±0.06</td>
</tr>
<tr>
<td>Hot air drying</td>
<td>0</td>
<td>77.31±0.03</td>
<td>129.62±0.07</td>
</tr>
</tbody>
</table>

CD ($P<0.05$) 0.810 4.748
SEM (±) 0.278 1.633
F value ** **

**Significant ($P<0.05$)
The degree of porosity ultimately affects the rehydration of dried products which was less in the case of hot air dried cubes leading to less rehydration ratio resulting in harder product even after rehydration (Contreras et al., 2005).

<table>
<thead>
<tr>
<th>Power (W)</th>
<th>Vacuum (mbar)</th>
<th>Hardness (N)</th>
<th>Springiness</th>
<th>Cohesiveness</th>
<th>Chewiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>-</td>
<td>25.42±0.02</td>
<td>0.70±0.001</td>
<td>0.47±0.002</td>
<td>8.75±0.04</td>
</tr>
<tr>
<td>Blanched</td>
<td>-</td>
<td>17.59±0.02</td>
<td>0.79±0.002</td>
<td>0.42±0.001</td>
<td>5.91±0.03</td>
</tr>
<tr>
<td>200</td>
<td>0</td>
<td>3.11±0.03</td>
<td>0.05±0.001</td>
<td>0.02±0.001</td>
<td>0.04±0.02</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>2.90±0.03</td>
<td>0.03±0.001</td>
<td>0.01±0.001</td>
<td>0.03±0.02</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>2.31±0.06</td>
<td>0.94±0.001</td>
<td>0.67±0.002</td>
<td>7.88±0.03</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>2.44±0.04</td>
<td>0.02±0.002</td>
<td>0.02±0.001</td>
<td>0.03±0.02</td>
</tr>
<tr>
<td>400</td>
<td>0</td>
<td>3.94±0.02</td>
<td>5.17±0.001</td>
<td>0.41±0.002</td>
<td>11.41±0.05</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>1.50±0.04</td>
<td>0.04±0.001</td>
<td>0.03±0.001</td>
<td>0.06±0.02</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>3.72±0.03</td>
<td>0.06±0.002</td>
<td>0.07±0.001</td>
<td>0.03±0.02</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>3.28±0.05</td>
<td>0.08±0.001</td>
<td>0.06±0.001</td>
<td>0.02±0.02</td>
</tr>
<tr>
<td>600</td>
<td>0</td>
<td>1.46±0.02</td>
<td>0.89±0.001</td>
<td>0.60±0.002</td>
<td>0.86±0.03</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>1.67±0.02</td>
<td>1.06±0.002</td>
<td>0.71±0.003</td>
<td>1.13±0.04</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>2.43±0.02</td>
<td>0.06±0.001</td>
<td>0.03±0.001</td>
<td>0.08±0.02</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>1.67±0.04</td>
<td>1.06±0.001</td>
<td>0.71±0.002</td>
<td>1.13±0.03</td>
</tr>
<tr>
<td>Hot air drying</td>
<td>0</td>
<td>2.97±0.02</td>
<td>3.02±0.002</td>
<td>0.62±0.002</td>
<td>0.58±0.02</td>
</tr>
<tr>
<td>CD (P&lt;0.05)</td>
<td></td>
<td>0.285</td>
<td>16.005</td>
<td>0.043</td>
<td>0.635</td>
</tr>
<tr>
<td>SEM (±)</td>
<td></td>
<td>0.099</td>
<td>5.541</td>
<td>0.014</td>
<td>0.220</td>
</tr>
<tr>
<td>F value</td>
<td></td>
<td>ns</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>

**Significant (P<0.05)

**Sensory attributes**

The potato cubes when subjected for sensory test showed varied responses from the panelist which is shown in Fig. 2. It is clear from the figure that the microwave dehydrated samples had been given significantly (P<0.05) higher sensory scores as compared to hot air dehydrated ones. The trend was same in the case of rehydrated samples too. The potato cubes dehydrated under microwave and vacuum conditions further recorded higher sensory scores, the maximum scores being in the case of samples dehydrated at 600 W and 150 mbar vacuum. The same samples showed highest sensory scores after rehydration. The potato cubes dehydrated under microwave and vacuum conditions showed faster absorption of water when put for rehydration due to their puff nature as compared to hot air dehydrated ones which took longer time for rehydration due to case hardening on their surface and shrinkage in the product. Soysal et al. (2009) reported better sensory characteristics in terms of visual appearance, colour, texture and overall acceptability in microwave dehydrated red peppers which was attributed to faster drying under microwave dehydration conditions. It has been reported that microwave-vacuum dried carrot slices received higher ratings for sensory properties such as texture, odour and overall acceptability as compared to air dried carrot slices (Lin et al., 1998). There was also an effect of microwave drying on the shelf
life and sensory attributes of coriander, mint, fenugreek and shepu (Fathima et al., 2001). These authors suggested that microwave drying was highly suitable for amaranth, moderately suitable for shepu and fenugreek and less suitable for coriander and mint.

![Graph](image)

**Fig. 2.** Overall sensory acceptability of dehydrated and rehydrated potato cubes

**Microstructural characteristics**

The scanning electron micrographs of the variously dehydrated potato cubes revealed that the microstructure of the tissue were more retained in vacuum assisted microwave dehydrated potato cubes as compared to hot air dehydrated ones (Fig. 3). The vacuum assisted microwave dehydrated samples showed more tissue integrity showing porous nature of the products which was due to fast vaporization of moisture present in the cubes during microwave vacuum drying. Vapor bubbles could increase total pressure gradient inside the cubes and, therefore, enhanced the porosity. Less shrinkage in the microwave-vacuum dried samples may also be due to shorter drying time, lower drying temperature and some tissue expansion from internal water vapour. Puffiness in the product is because of low pressure kept during drying, while the internal steam pressure within products was elevated. This pressure differential generates an outward force, causing the material to expand beyond its original dimensions resulting in a puffing effect. Increasing microwave power resulted in increase in evaporation rate, thereby, preventing shrinkage and case hardening. This could also be one of the factors in improvement in rehydration of dried potato cubes dehydrated under microwave and vacuum conditions, whereas, hot air drying at 60°C yielded packed tissue structure. Increasing microwave power tended to increase evaporation rate, thereby preventing shrinkage and case hardening. Similar results have also been reported in the case of dried mushrooms using microwave vacuum drying (Giri and Prasad, 2007).
Conclusions

Vacuum assisted microwave drying can be employed for dehydration of potato cubes having good rehydration qualities. Increase in microwave power level along with high vacuum yielded better quality product as compared to those dehydrated at low microwave power or low vacuum. The quality of the products dehydrated under microwave with or without application of vacuum was found to be much superior as compared to hot air dehydrated ones. The microwave dehydrated products showed better color, textural and structural integrity as compared to hot air dehydrated ones. Further, microwave dehydration reduced the drying time and can be used at industrial level for large scale production.

References


Botha, G.E., Oliveira, J.C., & Ahrne, L. (2012). Quality optimisation of combined osmotic dehydration and
microwave assisted air drying of pineapple using constant power emission. Food Bioproducts Processing, 90, 171-179.  
http://dx.doi.org/10.1016/j.fbp.2011.02.006

http://dx.doi.org/10.1016/j.lwt.2004.07.017

http://dx.doi.org/10.1016/j.jfoodeng.2004.01.008

http://dx.doi.org/10.1023/A:1011858604571

http://dx.doi.org/10.1111/j.1365-2621.1998.tb15811.x

http://dx.doi.org/10.1016/j.jfoodeng.2009.03.007

http://dx.doi.org/10.1016/j.jfoodeng.2005.10.021

http://dx.doi.org/10.1016/j.ifset.2007.06.009

http://dx.doi.org/10.1016/j.jssas.2010.05.001

http://dx.doi.org/10.1016/S0260-8774(97)00050-2

http://dx.doi.org/10.1080/0737399908917545


http://dx.doi.org/10.1016/S0260-8774(98)00022-3

http://dx.doi.org/10.1016/S0963-9969(98)00070-2

http://dx.doi.org/10.1016/j.ifset.2010.06.007

Maskan, M. (2001). Drying, shrinkage and rehydration characteristics of kiwifruits during hot air and...
http://dx.doi.org/10.1016/S0260-8774(00)00155-2

http://dx.doi.org/10.1016/S0260-8774(00)00154-0


http://dx.doi.org/10.1016/j.biosystemseng.2009.05.010

http://dx.doi.org/10.1016/j.lwt.2004.07.006

http://dx.doi.org/10.1081/DRT-120038588

http://dx.doi.org/10.1016/j.jfoodeng.2010.05.021

http://dx.doi.org/10.1016/j.jfoodeng.2006.06.019

http://dx.doi.org/10.1016/j.jfoodeng.2007.03.030

http://dx.doi.org/10.1111/j.1745-4549.1996.tb00851.x

eration, 20, 145-156.