American Journal of

# Food Technology

ISSN 1557-4571

Academic
Journals Inc.

www.academicjournals.com

American Journal of Food Technology 3 (2): 100-108, 2008
ISSN 1557-4571


# Microwave/Vacuum Drying of Cranberries (*Vacccinium macrocarpon*)

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**Abstract:** Mechanically pretreated (cut) and osmotically dehydrated cranberries (*Vaccinium macrocarpon*) were dried using microwaves (MW) under subatmospheric pressure. Two MW modes were tested (continuous and pulsed), two combinations of pulsed MW mode (30 sec on/30 sec off, 30 sec on/45 sec off) and three MW power levels (1.00, 1.25 and 1.50 W $g^{-1}$ of initial sample mass). Three vacuum levels were compared one to another (3.4, 18.6 and 33.8 kPa of absolute pressure). Several process and quality parameters such as time of drying, colour, toughness and rehydration ratio were measured and calculated in order to evaluate different drying conditions. Methods with higher overall MW input (1.25 and 1.5 W $g^{-1}$) and longer power-off time (45 sec) combined with high vacuum (3.4 kPa) offered high quality dried berries (colour parameters similar to those of fresh fruit, soft and chewable texture, juiciness and good rehydration properties).

**Key words:** Cranberry, fruit preservation, microwave drying, postharvest processing, quality control

## INTRODUCTION

One of the requirements of fruit preservation is to prolong shelf life as much as possible; if possible for the whole year until the next harvest. Another demand is the maintenance of original fruit properties to the fullest extent until delivered to the customer, such as appearance, taste, smell, aroma, nutritional content and many others. Fruit dehydration is out of many preservation methods used and drying is the most widely used dehydration method.

The use of microwaves in drying of fruits has been increased in the last few decades and it is mainly due to the easy process control, good microwave penetration into fruit tissues causing volumetric heating and shorter processing times (Sanga *et al*., 2000). Vacuum drying assumes low process temperatures and faster water evaporation, offering shorter drying times and higher quality of dried product compared to drying method without vacuum.

Combination of microwaves as a heat source and subatmospheric pressures has been a topic of many studies in food processing. Both methods have many advantages, which can be summarized as follows:

- Targeted heating, i.e., heating of water molecules inside a product and therefore heat damage to surrounding tissues is reduced to minimum.
- Instantaneous energy transfer from microwaves to water molecules.
- Lower temperature of process when compared to convective drying, due to reduction of water boiling temperature with reduction of absolute pressure.

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Fruits and vegetables have been used as a material for microwave/vacuum drying in many studies. Lin *et al*. (1998) compared quality parameters such as colour, density, rehydration properties, textural characteristics and nutritional value of carrot in three methods of drying: microwave/vacuum, hot-air and freeze drying. In all parameters, MW/vacuum drying showed better results than air drying and equal or better than freeze drying except in rehydration potential, nutritive value and appearance. Clary and Ostrom (1995) Dried grapes of Thomson seedless variety under MW/vacuum and they concluded that this method is a viable alternative to conventional air drying of grapes. Bananas were dried in study of Drouzas and Schubert (1996) using MW and subatmospheric pressure. MW were used in pulsed mode (10 sec on/20 sec off), which can slow down burning of a dried product if continuous mode is used.

Apple, kiwi and pear were MW/vacuum dried in a study by Kiranoudis *et al*. (1997) and the conclusion is that MW power had significant influence on the model proposed, but vacuum showed no statistically significant influence. Drouzas *et al*. (1999) studied drying kinetics of MW/vacuum drying in fruit gels and confirmed that drying rate increased with higher power input and lower absolute pressure in vacuum drying. They compared the colour of MW/vacuum dried fruit gel with MW/convective dried gel and concluded that MW/vacuum drying offered better colour properties of dried product.

This method of drying is particularly suitable for the sensitive products, such as spices. Yousif *et al*. (2000) compared dried oregano with MW/vacuum, air and freeze drying methods. MW/vacuum and freeze-dried oregano showed no significant difference when compared to the fresh oregano plant, whereas air-dried samples were darker and with reduced flavour volatiles. Onion is one of the appropriate commodities to be dried under vacuum and MW, because it is very sensitive to high temperatures and volatile compounds are easily lost in convective drying. Chen and Chiu (1999) dried onion at 600 W microwave power under 100 torr (13.33 kPa) of absolute pressure and reported that this method of drying can overcome heat and moisture transfer resistance, have a fast drying rate and high volatile retention.

Gunasekaran (1999) in his study on pulsed MW/vacuum drying discussed results of several authors. He indicated that pulsed MW drying can be more energy efficient than continuous and that shorter power-on time and longer power-off time can improve product quality and overall energy efficiency.

Microwave/vacuum drying of cranberries has been the main topic of research in the study of Yongsawatdigul and Gunasekaran (1996a, b), where they used osmotically pretreated cranberries and dried them under continuous and pulsed MW power mode, using two levels of absolute pressure. Pulsed mode was more energy effective than continuous and gave the product with higher quality parameters such as colour, texture, rehydration properties and others. The attributes of quality parameters were better when compared to air-dried berries and store-bought. Mechanically pretreated and osmotically dehydrated cranberries were dried using different methods (Grabowski *et al*., 2002). These methods were freeze-drying, vacuum drying and convective drying in four dryer types. The criteria for comparison among these methods were energy consumption and product quality. Regarding product quality, freeze drying showed the best characteristics in anthocyanins content, rehydration ratio, colour and taste. Energy efficiency was higher in vibrated fluid bed and the pulsed bed dryer than in other dryer types.

The only available work on this topic were from Yongsawatdigul and Gunasekaran (1996a, b) and the scarcity of MW/vacuum drying work on small fruit such as cranberries was one of the reasons to perform this research.

The objectives of this study can be summarized as follows:

- To establish the best drying conditions for cranberries using microwaves as an energy source, with application of low absolute pressure in order to reduce process temperature.

The hypothesis is that microwave/vacuum drying can lead to a better quality product, with good retention of original fruit characteristics.

## MATERIALS AND METHODS

This study was performed in the Department of Bioresource Engineering of McGill University, Canada, in 2002, 2003.

### Cranberry Pretreatment

Mechanically pretreated (cut in quarters) thawed cranberries of Stevens cultivar harvested by hand in Quebec were subjected to osmotic dehydration with High Fructose Corn Syrup (HFCS) for 24 h. The factors of osmotic dehydration process were: 2:1 mass ratio of syrup to fruit, HFCS used was 77°Brix-Invertose 2655 and process temperature was 23±1°C. Initial moisture of cranberries is 88%±1°C and during osmotic dehydration it has reduced to 55±1%.

### Microwave/Vacuum Drying

In this study the influence of several process parameter on the quality of final product will be tested. Parameters such as MW power level, MW power mode and the pressure applied. Microwave/vacuum drying equipment is shown in Fig. 1.

After osmotic dehydration, samples of 100±1 g were dried. This sample size was used in order to facilitate subsequent calculations. Moisture of these samples was 55±1%. Samples were placed in a 3 cm layer, in a thick-wall glass jar, used as a vacuum chamber. Glass was considered as completely transparent to MW. This container was placed on a balance inside of MW chamber, but vacuum hose, which touched MW chamber wall, affected the mass measurement. Nevertheless, mass measured was a satisfactory indicator of drying progress, because running several tests under the same conditions for each method predetermined total drying time and the average time was verified by sample mass shown on the balance. Container was connected with a desiccator and vacuum pump (John Scientific Inc., Canada). Desiccator with anhydrous $CaSO_4$ served to remove the moisture, because it is dangerous if moisture enters the pump. The real-time temperature of a sample surface layer was monitored using an optical fibre (Fisher Scientific, Canada) placed in one of the cranberries close to the surface.

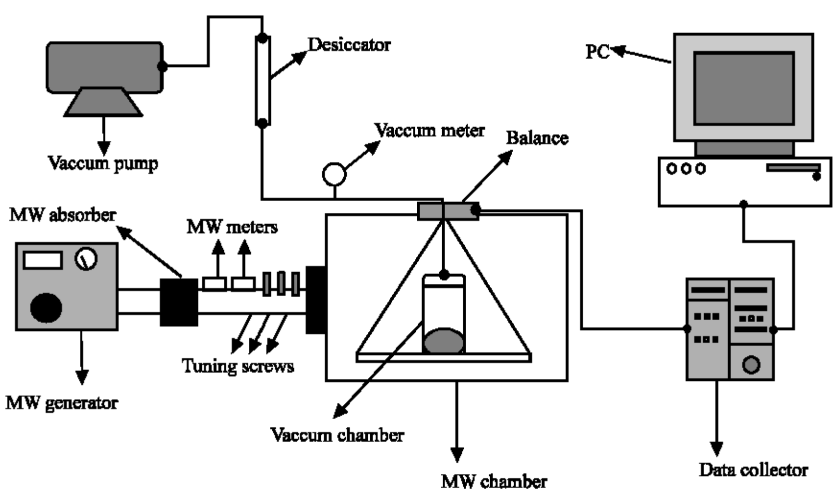


Fig. 1: Schematic representation of MW/vacuum drying equipment

A laboratory-scale microwave oven was modified and used to perform the tests. Microwaves were generated by a 750 W, 2450 MHZ microwave generator, whose power can be modulated and traveled through rectangular wave-guides to the microwave cavity. A circulator which directed reflected MW to a dummy load (carbon rod) ensured their proper absorption and tuning screws inserted at the top of the wave-guide assembly permitted to maintain the reflected power close to zero during the process.

Three power levels were tested: 100, 125 and 150 W; or 1.00, 1.25 and 1.5 W $g^{-1}$ of initial sample mass, respectively. Three MW power modes were applied: continuous, 30 sec on/30 sec off and 30 sec on/45 sec off. The effect of pressure on product quality parameters was tested under three levels of absolute pressure: 3.4, 18.6 and 33.8 kPa.

### Quality Evaluation

Tested quality parameters were colour parameters, textural properties and rehydration ratio. Quality analysis was performed on the final product, i.e. dried cranberries with 15±1% of moisture (wet basis).

Time of process was used as one of the process parameters and it served to calculate the overall drying efficiency following Eq. 1 (Yongsawatdigul and Gunasekaran, 1996a):

$$DE = \frac{M_i \cdot (m_i - m_f)}{t_{on} \cdot P \cdot (1 - m_f)} \tag{1}$$

Where:

DE = Drying performance (kg of evaporated water $J^{-1}$ of supplied energy)
$t_{on}$ = Total time of MW power-on (sec)
P = MW power input (W)
$m_i$, $m_f$ = Initial and final moisture contents (ratios, wet basis)
Mi = Initial sample mass (kg wet basis)

Colour was measured using a chromameter (Model CR-300X, Minolta camera Co. ltd., Japan) equipped with a 5 mm diameter measuring area. The results were expressed as Hunter coordinates: L* (whiteness/darkness, ranged from 0 to 100, 100 being the lightest), a* (redness for the positive value, greenness for the negative ones) and b* (yellowness for the positive value, blueness for the negative ones) (McGuire, 1992). Then the data obtained were converted to hue angle (h°), Chroma C* (colour saturation) and overall colour difference ΔE were calculated, following:

$$h^\circ = \arctan\frac{b^*}{a^*} \tag{2}$$

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \tag{3}$$

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \tag{4}$$

Where:

$$\Delta L^* = L^* - L^*_{st} \tag{5}$$

$$\Delta a^* = a^* - a^*_{st} \tag{6}$$

$$\Delta b^* = b^* - b^*_{st} \tag{7}$$

$L^*_{st}$, $a^*_{st}$ and $b^*_{st}$ are Hunter values of the standard (fresh cranberries).

Textural properties of dried fruit were measured on the Instron Universal testing machine (Series IX Automated Materials Testing System 1.16). For small fruits such as cranberries, the probe element was a Kramer shear press. A 50 kN load cell was used and the speed of crosshead was 160 mm $min^{-1}$. The parameters obtained on the instrument were Young's modulus (MPa) and toughness (MPa). Young's Modulus is the stress of a material divided by its strain. That is how much the material yields for each mass unit kg or pound of load put on it. The toughness of a material is the area under a stress-strain curve. The stress is proportional to the tensile force on the material and the strain is proportional to its length.

One of the most important parameters of dried product quality is its ability to rehydrate, or to infuse water again. Cranberries are often used in cereals and they must have high rehydration ratio. Rehydration ratio was calculated using the following expression (modified from Venkatachalapathy and Raghavan, 1998):

$$RR = 10 \cdot \left( \frac{M_{rh} \cdot (100 - m_{in})}{M_{dr} \cdot (100 - m_{dr})} \right) \quad (8)$$

Where:

RR = Rehydration ratio (ratio)

$M_{rh}$ and $M_{dr}$ = Mass of rehydrated and dried sample (g)

$m_{in}$ and $m_{dr}$ = Moisture contents of the sample before and after drying (%, wet basis)

**Experimental Design**

All experiments were conducted in three replicates and the data obtained were subjected to Analysis of Variance (ANOVA) using SAS/STAT Software (SAS Institute Co.) version 8.0. Experimental design was completely randomized block design. Duncan's multiple range tests for pairwise comparison of each variable was used for finding differences among the treatments. Differences were determined as significant or non-significant at a significance level of 0.05 in all cases.

## RESULTS

**Drying Efficiency**

MW power had a significant influence on drying time and drying efficiency, as well as MW mode applied. But, pressure didn't have any significant influence on the drying time and drying efficiency (Table 1, 2).

The conclusion can be that higher power levels and modes with shorter power-off time can offer lower energy consumption exhibited through increased drying efficiency. It must be noted that DE was calculated only using power obtained from MW and not from vacuum pump.

Table 1: Average values of total drying time, power-on drying time and drying efficiency for cranberries dried at 3.4 Kpa of absolute pressure

| MW power ($W\ g^{-1}$) | MW mode | Total drying time (min) | Power-on drying time (min) | Drying efficiency ($kg_{water}\ J^{-1}$) |
|---|---|---|---|---|
| 1 | Continuous | $33.75^{e}$ | 33.75 | $0.238^{c}$ |
| 1 | 30 sec on/30 sec off | $88.50^{b}$ | 44.25 | $0.182^{b}$ |
| 1 | 30 sec on/45 sec off | $152.75^{a}$ | 61.10 | $0.132^{a}$ |
| 1.25 | Continuous | $19.00^{f}$ | 19.00 | $0.339^{d,e,f}$ |
| 1.25 | 30 sec on/30 sec off | $36.50^{e}$ | 18.25 | $0.352^{e,f}$ |
| 1.25 | 30 sec on/45 sec off | $53.25^{c}$ | 21.30 | $0.302^{d}$ |
| 1.5 | Continuous | $13.50^{g}$ | 13.50 | $0.397^{f}$ |
| 1.5 | 30 sec on/30 sec off | $32.25^{e}$ | 16.13 | $0.332^{d,e}$ |
| 1.5 | 30 sec on/45 sec off | $43.25^{d}$ | 17.30 | $0.310^{d,e}$ |

Duncan's groupings: Means with the same letter(s) are not significantly different

Table 2: Average values of total drying time, power-on drying time and drying efficiency of cranberries dried with 125 W power level and MW mode of 30 sec on/30 sec off, under different absolute pressures

| Absolute pressure (kPa) | Total drying time (min) | Power-on drying time (min) | Drying efficiency ($kg_{water}$ $J^{-1}$) |
|---|---|---|---|
| 3.4 | $36.50^{a}$ | 18.25 | $0.352^{a}$ |
| 18.6 | $37.25^{a}$ | 18.63 | $0.345^{a}$ |
| 33.8 | $39.75^{a}$ | 19.88 | $0.324^{a}$ |

Duncan's groupings: Means with the same letter(s) are not significantly different

Table 3: Average colour values for cranberries dried under different MW power levels and MW modes, at 3.4 kpa

| MW power (W $g^{-1}$) | MW mode | L* | a* | b* | h° | C* | ΔE |
|---|---|---|---|---|---|---|---|
| 1 | Continuous | $30.18^{b}$ | $29.90^{b}$ | $13.77^{a}$ | $24.77^{a,b}$ | $32.94^{e}$ | $9.78^{a}$ |
| 1 | 30 sec on/30 sec off | $32.39^{a,b}$ | $35.15^{b,c}$ | $14.92^{a}$ | $23.05^{a,b}$ | $38.20^{b,c}$ | $5.99^{a-c}$ |
| 1 | 30 sec on/45 sec off | $36.95^{a}$ | $39.63^{a}$ | $14.68^{a}$ | $20.30^{a,b}$ | $42.29^{a}$ | $5.90^{a-c}$ |
| 1.25 | Continuous | $31.02^{a,b}$ | $30.21^{d}$ | $14.41^{a}$ | $25.46^{a}$ | $33.49^{d,e}$ | $9.30^{a,b}$ |
| 1.25 | 30 sec on/30 sec off | $31.59^{a,b}$ | $31.26^{d,c}$ | $14.44^{a}$ | $24.90^{a,b}$ | $34.46^{c-e}$ | $9.04^{a,b}$ |
| 1.25 | 30 sec on/45 sec off | $33.94^{a,b}$ | $35.31^{b}$ | $15.57^{a}$ | $23.82^{a,b}$ | $38.63^{a,b}$ | $4.00^{c}$ |
| 1.5 | Continuous | $30.47^{b}$ | $29.52^{d}$ | $13.96^{a}$ | $25.33^{a}$ | $32.66^{e}$ | $9.87^{a}$ |
| 1.5 | 30 sec on/30 sec off | $31.26^{a,b}$ | $34.51^{b,c}$ | $13.99^{a}$ | $22.23^{a,b}$ | $37.31^{b-d}$ | $7.98^{a,b}$ |
| 1.5 | 30 sec on/45 sec off | $32.91^{a,b}$ | $35.74^{b}$ | $14.58^{a}$ | $22.11^{a,b}$ | $38.68^{a,b}$ | $5.29^{b,c}$ |

Duncan's groupings: Means with the same letter(s) are not significantly different

Table 4: Average colour values of cranberries dried with 100 W power level and MW mode of 30 sec on/30 sec off under different absolute pressures

| Absolute pressure (kPa) | L* | a* | b* | h° | C* | ΔE |
|---|---|---|---|---|---|---|
| 3.4 | $32.39^{a}$ | $35.15^{a}$ | $14.92^{a}$ | $23.05^{b}$ | $38.19^{a}$ | $5.98^{a}$ |
| 18.6 | $31.32^{a}$ | $30.87^{b}$ | $15.58^{a}$ | $26.80^{a}$ | $34.59^{b}$ | $8.02^{a}$ |
| 33.8 | $31.79^{a}$ | $28.86^{b}$ | $15.41^{a}$ | $28.11^{a}$ | $32.72^{b}$ | $9.30^{a}$ |

Duncan's groupings: Means with the same letter(s) are not significantly different

## Colour Parameters

Colour parameters were evaluated for each drying method and the results are shown in Table 3. It can be seen that both MW power and MW mode had a significant influence on lightness L*, redness a*, hue angle h°, chroma value C* and colour difference ΔE. The only colour parameter without any significant influences was yellowness b*. It should be noted that methods with longer power-off time (30 sec on/45 sec off) showed better values for colour difference ΔE for all MW power levels. On the other hand, pressure didn't show any major effect on cranberry colour. Table 4 shows the influence of applied vacuum on the colour parameters, but this parameter had influence only on three colour values: redness a*, hue angle h° and chroma value C*. Other values (L*, b* and ΔE) were not significantly affected with changed operating pressure. The absolute pressure of 3.4 kPa showed significantly higher redness, lower hue angle and higher chroma value, but compared to standard (fresh cranberries expressed through ΔE) pressure didn't have any significant influence.

In order to obtain colour of dried berries similar to fresh cranberries, the method with higher MW power level should be used (1.25 and 1.5 W $g^{-1}$) and with pulsed MW mode with shorter power-on and longer power-off time (30 s power-on/45 sec power-off). It has to be mentioned that all samples did have between 5 and 15% (mass %) of burned fruit that were completely black. This is due to low uniformity of heat distribution in immobile sample. Colour measurements were taken only on unburned sample part.

## Textural Properties

Textural properties are very important characteristics of dried fruits. For each drying method, two textural properties were assessed: Young's modulus and toughness, both expressed in MPa.

Textural characteristics had different response to drying conditions for the two tested parameters. From Table 7, it is observed that methods with 1.25 W $g^{-1}$ and pulsed MW modes, as well as method

Table 5: Average values of Young's modulus and toughness of cranberries dried with 125 W power level and MW mode of 30 sec on/30 sec off under different absolute pressures

| Absolute pressure (kPa) | Young's modulus (MPa) | Toughness (MPa) |
|---|---|---|
| 3.4 | 6.36[a] | 0.0176[a] |
| 18.6 | 6.66[a] | 0.0156[a] |
| 33.8 | 6.22[a] | 0.0145[a] |

Duncan's groupings: Means with the same letter(s) are not significantly different

Table 6: Average values of rehydration ratios for cranberries dried with 125 W power level and MW mode of 30 sec on/30 sec off under different absolute pressures

| Absolute pressure (kPa) | Rehydration ratio |
|---|---|
| 3.4 | 2.64[a] |
| 18.6 | 2.51[a,b] |
| 33.8 | 2.44[b] |

Duncan's groupings: Means with the same letter(s) are not significantly different

Table 7: Average values of Young's modulus, Toughness and Rehydration Ratios for cranberries dried under different MW powers and MW modes at 3.4 kPa of absolute pressure

| MW power ($W g^{-1}$) | MW mode (sec on/sec off) | Young's modulus (MPa) | Toughness (MPa) | Rehydration ratio |
|---|---|---|---|---|
| 1 | Continuous | 8.17[a] | 0.0180[a] | 2.52[a,b,c] |
| | 30/30 | 8.14[a] | 0.0166[a] | 2.32[c,d] |
| | 30/45 | 7.91[a] | 0.0158[a] | 2.28[d] |
| 1.25 | Continuous | 7.94[a] | 0.0190[a] | 2.67[a] |
| | 30/30 | 6.36[b] | 0.0176[a] | 2.64[a] |
| | 30/45 | 6.30[b] | 0.0171[a] | 2.57[a,b] |
| 1.5 | Continuous | 8.02[a] | 0.0200[a] | 2.66[a] |
| | 30/30 | 7.04[a,b] | 0.0176[a] | 2.61[a] |
| | 30/45 | 6.69[b] | 0.0165[a] | 2.40[b,c,d] |

Duncan's groupings: Means with the same letter(s) are not significantly different

with 1.5 W $g^{-1}$ and pulsed mode of 30 sec on/45 sec off had significantly lower Young's modulus, meaning that they have lower stiffness. Both MW power and MW modes had significant effect on Young's modulus. On the other hand, toughness of cranberries was not significantly influenced by any methods applied. Different pressures did not have significant influence on both texture parameters and this can be shown in Table 5.

With the purpose of obtaining a product of good textural characteristics (soft, chewy), the drying method should be with higher MW power levels and pulsed MW modes of shorter power-on and longer power-off time, similar to the requirement observed for colour characteristics. Continuous MW mode showed as expected fruit with higher Young's modulus and with increasing of MW power off time, this parameter gradually decreased.

**Rehydration Ratio**

Rehydration ratios were significantly affected by all three process parameters: MW power level, MW mode and pressure applied. Higher RR values were observed with MW power level of 1.25 W $g^{-1}$ and partially 1.5 W $g^{-1}$. The same pulsed MW modes should be applied as for colour and texture optimization: 30 sec power on/45 sec power off. This was the only parameter on which vacuum had significant influence and preferential treatment is with lower absolute pressure (higher vacuum) of 3.4 kPa.

It can be concluded from Table 6 and 7 that MW power level of 1.25 W $g^{-1}$ offers the best conditions for high RR and that MW mode of 30 sec on/45 sec off is also very beneficial to rehydration properties, as well as higher vacuum. Longer power off time provides enough time for cranberry to redistribute moisture and higher vacuum creates effective environment for the preservation of fruit tissue preservation.

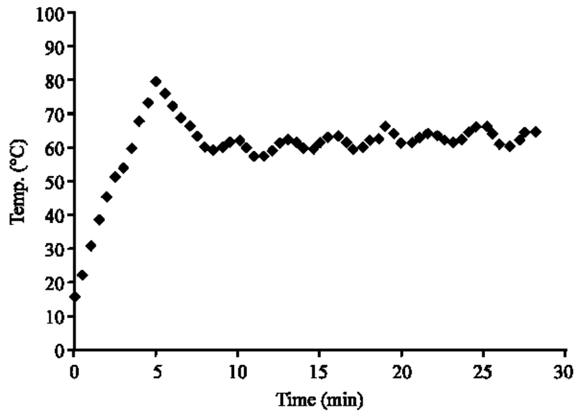


Fig. 2: Real-time temperature of a surface cranberry layer for the 1 W $g^{-1}$, 30 sec on/30 sec off, 3.4 kPa drying method

**Temperature**

The purpose of temperature monitoring was to record temperature change during drying. Surface temperature profile was taken for 1 W $g^{-1}$, 30 sec on/30 sec off, 3.4 kPa method. Fig. 2 shows that surface layer of cranberry sample reached after five minutes its maximum: almost 90°C and shortly after it stabilized around 60°C. This can be explained by high moisture content at the beginning of process, where this excess of moisture absorbs more MW energy causing higher temperature reading. Expected temperature of approximately 27°C (temperature of water evaporation at 3.4 kPa) was not noticeable, probably because of internal heat build-up and increased temperature of the sample. Heat build-up is evident because of poor distribution of MW field inside MW chamber, as explained by Zhang *et al*. (2006).

## DISCUSSION

MW drying combined with subatmospheric pressures can be used to dry cranberries more rapidly than conventional air-drying (Beaudry *et al*., 2003, 2004). This method also offers product with higher quality parameters when compared to combined MW/convective drying (Sunjka *et al*., 2004).

The purpose of this study was to establish optimal process parameters such as drying time, MW power mode and level and vacuum applied. The results obtained confirmed those from (Yongsawatdigul and Gunasekaran, 1996a, b). Overall conclusion is that quality dried cranberries can be obtained by MW/vacuum drying, using higher power levels (shorter drying time) and pulsed MW modes with shorter power-on and longer power-off time. Longer power-off time is beneficial for water redistribution inside the fruit, giving more uniformly dried product, with better rehydration properties. Higher vacuum is preferable, guarantying lower process temperature. Therefore, MW/vacuum drying is a feasible method for drying of osmotically dehydrated cranberries.

Undesirable feature of MW drying is low heat uniformity of dried product. This was obvious in all experiments, especially in those with higher MW power levels and continuous mode, causing burned, almost carbonized spots in the centre of vacuum container. Composite foods such as cranberries have low thermal conductivity and can make thermal avalanches making temperature control difficult (Gunasekaran, 1999). This problem can be alleviated by placing the sample on a rotating tray or moving belt. In addition, bigger samples and larger MW chamber should be used, in order to enhance the distribution of microwaves.

## ACKNOWLEDGMENTS

The authors would like to express their gratitude towards Natural Sciences and Engineering Research Council of Canada (NSERC) for their financial support, to Mr. Timothy John Rennie and Mr. Yvan Gariépy for their recommendations and technical assistance during this research.

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