
Assessment of pretreatment methods and osmotic dehydration for cranberries

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Sunjka, P.S. and Raghavan, G.S.V. 2004. **Assessment of pretreatment methods and osmotic dehydration for cranberries.** Canadian Biosystems Engineering/Le génie des biosystèmes au Canada 46: 3.35-3.40. In this research, different drying pretreatment methods were tested on cranberry fruit (*Vaccinium macrocarpon*). Mechanical and chemical pretreatments were examined, as well as osmotic dehydration. Two types of assessed mechanical pretreatments were cutting the berries in halves and into quarters and chemical pretreatment consisted of testing different temperatures of chemical agent and dipping times for cranberries. Osmotic dehydration involved evaluation of different osmotic agents, their concentrations, and different times of osmotic dehydration. There were three observed parameters: mass gain, solids gain, and moisture loss. The mechanical pretreatment that showed the best results for observed parameters was cutting the berries into quarters, but chemical pretreatment showed no significant difference. Time and concentration of osmotic agent significantly promoted the moisture removal and sugar uptake. **Keywords:** cranberry, drying pretreatment, moisture loss, osmotic dehydration.

Dans cette étude, différentes méthodes de prétraitement pour le séchage de la canneberge (*Vaccinium macrocarpon*) ont été évaluées. À savoir, la méthode mécanique, la méthode chimique et la méthode de déshydratation osmotique. En ce qui concerne la méthode mécanique, deux types de prétraitements ont été utilisés : le découpage en deux ou en quatre des canneberges. La méthode chimique consistait à optimiser température des agents chimiques et la durée d'immersion des canneberges. La méthode de déshydratation osmotique impliquait l'évaluation des différents agents osmotiques, des concentrations, ainsi que des durées du prétraitement. Les paramètres utilisés pour comparer les méthodes étaient: le gain de masse du fruit, le gain des solides solubles, et la perte d'eau. Les meilleurs résultats ont été obtenus avec le prétraitement mécanique avec découpage des baies en quatre quartiers. Le prétraitement chimique n'a montré aucune avantage sur les baies non traitées. Le temps et la concentration de l'agent osmotique avaient accentué l'élimination d'eau et d'accumulation de sucre dans les baies.

INTRODUCTION

Drying of fruits and vegetables is one of the most time and energy consuming processes in the modern food industry. To reduce the processing time, thus facilitating and accelerating the dehydration process, a number of obstacles must be overcome. The main problem in this food preservation method is the outer layer of a particular commodity, the skin. The skin impedes water transport from the interior of a food product to its surface, slowing the drying process.

There are two main methods to reduce the effects of skin resistance and promote water transport, chemical and mechanical pretreatments. Chemical pretreatment involves

dipping of a product into a chemical solution (normally alkaline or acid solution of oleate esters) of a specific concentration for a specific amount of time. Mechanical pretreatment consists of skin abrasion, puncturing, or cutting the product into smaller pieces.

One of the most useful pretreatments for drying of fruit is osmotic dehydration (Beaudry 2001). Osmotic dehydration is the incomplete removal of water from a food product by means of an osmotic agent (usually either sugar or salt solution). The main advantage of this process is its influence on the principal drying method, shortening of the drying process, resulting in lower energy requirements. Considering that heat is not applied in this stage, osmotic dehydration offers higher retention of initial food characteristics, such as colour, aroma, nutritional constituents, and flavour compounds (Beaudry 2001).

Skin pretreatment

Chemical pretreatment involves immersion of the product in alkaline or acid solutions of oleate esters prior to drying. Alkaline dipping facilitates drying by forming fine cracks on fruit surface (Salunkhe et al. 1991), and dipping in oleate esters causes wax platelets on the fruit skin to dissociate, helping the removal of moisture (Venkatachalapathy 1998).

It was determined by Ponting and McBean (1970) that, for fruits with a waxy surface layer, the most effective treatment is with ethyl esters of fatty acids, especially oleic acid. Saravacos et al. (1988) and Tulasidas et al. (1994) used ethyl oleate (EO) as a pretreatment, and found that it can improve the drying rate with only a minor effect on product quality. Venkatachalapathy (1998) used an alkaline solution of 2% EO and 0.5% sodium hydroxide (NaOH) as a pretreatment for strawberries and blueberries. Beaudry (2001) tested different concentrations and time periods of dipping for cranberries and concluded that these have no significant influence on subsequent osmotic dehydration.

Mechanical pretreatment might replace or complement chemical pretreatment, mainly because consumers hesitate to buy chemically treated fruits, and it has a profound effect on the later drying process. Mechanical pretreatment consists of peeling, surface abrasion, and cutting in various shapes, such as halves, cylinders, and cubes. A number of researchers (Shi and Maupoey 1993; Jia et al. 1993; Kiranoudis et al. 1997) used some kind of mechanical treatment to accelerate mass transfer in subsequent processing. There are several methods that can be applied (Beaudry 2001), puncture the skin by a needle, cut the berry in halves or quarters, and abrade the skin surface. All these mechanical pretreatments are used to increase the "active" skin surface where water can penetrate.

Mechanical pretreatment of cranberries was also recorded by Yongsawatdigul and Gunasekaran (1996), where they cut cranberries in halves. Beaudry (2001) examined different skin pretreatment techniques on cranberries, cutting into halves, abrading the surface of the skin and puncturing of the skin by a needle, and demonstrated that cutting in half is the best possible method to attain moisture loss.

Osmotic dehydration

Quality and processing costs are the two most important factors when choosing a food preservation method. Economic factors and quality improvement have primarily motivated application of the osmosis principle. Drying of high moisture fruit, such as cranberries, is time and energy consuming because such fruit is difficult to dry in one step. Osmotic dehydration is a preservation method that offers a high quality product by means of water removal without phase change. Osmotically dehydrated fruits have a good retention of flavour, aroma, and high nutritional content because osmotic dehydration has low influence on mineral content and vitamin loss; it preserves organoleptic properties (Barbosa-Cánovas and Vega-Mercado 1996).

During osmotic dehydration, a two-way counter-flow of mass exchange takes place (Lenart 1996). There is water diffusion from the sample to a surrounding hypertonic solution and an opposite stream of osmotic substances (sugar, salt, etc.) that enters the fruit.

Water removes water-soluble substances such as saccharides, organic acids, vitamins, etc. However, this loss is not significant, except for a minor deficit in nutritive value and a small change in organoleptic properties (Lenart 1996).

The objectives of the present study were to estimate optimal conditions for the chemical and mechanical skin pretreatment of cranberries, as well as the different conditions of osmotic dehydration prior to drying.

MATERIALS and METHODS

Each test was performed on thawed cranberries (*Vaccinium macrocarpon*) of the Stevens cultivar. These cranberries were cultivated and harvested from sandy and organic soils in the Montérégie region in Quebec. Prior to each experiment, the cranberries were thawed by immersion in water at room temperature ($23\pm 1^\circ\text{C}$) for one hour before being used for tests.

Chemical and mechanical pretreatment

Chemical pretreatment Chemical pretreatment was tested for multiple variables, such as time of immersion and the temperature of the particular chemical applied. Tests were performed using a solution of 2% EO and 0.5% NaOH (mass basis) in distilled water. This concentration of EO and NaOH was recommended by Beaudry (2001). Liquid EO was previously kept in a freezer at -20°C , and granular NaOH at ambient temperature.

After thawing, cranberries were wiped with soft tissues and immersed in a prepared alkaline EO solution for a specific time and at a specific temperature. Two levels of dipping time were tested, 60 and 180 seconds, and three temperatures of solution, ambient ($23\pm 1^\circ\text{C}$), $45\pm 1^\circ\text{C}$, and $65\pm 1^\circ\text{C}$. All experiments were performed four times. Afterwards, cranberries were rinsed with warm tap water (approximately 40°C) and wiped again with

tissues. Then, for all chemical pretreatment method combinations, the mechanical pretreatment (cut in quarters) and the osmotic dehydration method (24 hours, room temperature, HFCS with 1:1 and 2:1 concentrations) were followed in order to maintain other process conditions constant.

After 24 hours, the cranberries were rinsed of HFCS syrup, wiped with tissues, and air-dried (placed on a table) for 15-20 minutes to remove surface moisture. At that moment, mass was recorded and the final moisture content was determined by placing cranberries in an oven set at 70°C , until sample mass became constant (modified AOAC standard, Boland 1984).

Mechanical pretreatment Upon evaluation of optimal chemical pretreatment (pretreatment that offers the highest moisture loss in subsequent osmotic dehydration), two mechanical pretreatments were compared to the standard (no mechanical pretreatment). The pretreatments were cutting the berries in halves and in quarters with a stainless steel knife. All other parameters were the same, no chemical pretreatment, osmotic dehydration as described above (24 hours, room temperature, HFCS with 1:1 and 2:1 concentrations). All experiments were performed four times.

Osmotic dehydration

Once optimal chemical and mechanical pretreatments were determined, different factors of osmotic dehydration were tested. These factors and their levels were:

- Type of sugar agent (crystal sucrose, HFCS)
- Concentration of sugar agent (mass ratio of fruit to sucrose 1:1, 2:1, 3:1, and 4:1; mass ratio of fruit to HFCS 1:1 and 2:1)
- Time of osmotic dehydration (12, 24, 36, and 48 h)

Sugar agents were commercially available special fine granulated sugar and HFCS (Invertose 2655, at $77\pm 1^\circ\text{Brix}$). All tests were performed four times at ambient temperature ($23\pm 1^\circ\text{C}$). All other parameters remained constant during the experiment, no chemical pretreatment and cranberries cut in quarters.

After a defined time of dehydration, cranberries were removed from the sugar solution and rinsed under warm tap water (approximately 40°C), gently wiped with a soft tissue, and left for 15-20 minutes in ambient air in order to remove surface moisture. Mass at that moment was recorded, the cranberries were placed in an oven at 70°C until their mass became constant, and then the mass was recorded again.

Quality evaluation

Numerous quality parameters were monitored during this experiment:

- Initial ($88\pm 1\%$) and final moisture contents
- Initial ($6\pm 1.0^\circ\text{Bx}$ for sample and $77\pm 0.5^\circ\text{Bx}$ for HFCS) and final sugar content in $^\circ\text{Brix}$ for sample and HFCS
- Mass loss
- Solids gain
- Moisture loss

Initial and final sugar content in $^\circ\text{Brix}$ of samples and HFCS solutions were determined with a handheld refractometer (Fisherbrand by Fisher Scientific, Nepean, ON). The fruits were pressed in order to obtain one drop of juice, used for measuring.

Table 1. Average change in sugar and moisture content for chemically treated and osmotically dehydrated cranberries under the same conditions (HFCS, 24 h, mass ratio 2:1, room temperature).

Chemical pretreatment		Sugar (°Brix)				Moisture (% wb)	
Temperature (°C)	Time (s)	Cranberries		HFCS		Initial	Final
		Initial	Final	Initial	Final		
23	60	6.0	47.5 b	77.0	69.4 b	88.0	46.6 b
	180	6.0	48.3 b	77.0	63.5	88.0	45.9 b
45	60	6.0	39.0 c	77.0	73.5 a	88.0	50.7 a
	180	6.0	54.2 a	77.0	67.5 b,c	88.0	48.9 a
65	60	6.0	52.1 a,b	77.0	64.3 d,c	88.0	45.2 b,c
	180	6.0	54.5 a	77.0	66.6 d,c	88.0	44.7 b,c
Standard (no chemical pretreatment)		6.0	52.3 a,b	77.0	66.4 d,c	88.0	43.5c

Duncan groupings: Means with the same letters are not significantly different.

Mass loss, solids gain, and moisture loss were calculated using Eqs. 1 to 3, respectively (Beaudry 2001):

$$m_{gain} = \frac{m_{fin} - m_{ini}}{m_{ini}} \times 100 \quad (1)$$

$$s_{gain} = \frac{m_{sfin} - m_{sin}}{m_{ini}} \times 100 \quad (2)$$

$$W_{loss} = \frac{M_{ini} - M_{fin}}{M_{ini}} \times 100 \quad (3)$$

where:

- m_{gain} = mass gain (%),
- m_{fin} = total mass after osmosis (g),
- m_{ini} = initial mass before osmosis (g),
- s_{gain} = solids gain (%),
- m_{sfin} = mass solids after osmosis (g),
- m_{sin} = mass solids before osmosis (g),
- W_{loss} = moisture loss (%),
- M_{ini} = initial moisture content (% wb), and
- M_{fin} = final moisture content (% wb).

Equations 1 to 3 provide a quantitative description of component transfer under osmotic dehydration.

Experimental design

All experiments were performed in four replicates in order to assure better analysis of the statistical data. The data were subjected to the analysis of variance (ANOVA) and to Duncan's multiple range tests for pairwise comparison of each variable. Differences were determined as significant or non-significant at a significance level of 0.05 in all cases.

RESULTS and DISCUSSION

Chemical and mechanical pre-treatment

Chemical pre-treatment Chemically pretreated cranberries showed similar results to the standard sample (no chemical pretreatment) for the majority of observed parameters. There was some significance for some of the parameters, but the standard gave better results in solids gain and moisture loss values. Thus, it can be concluded that chemical pretreatment has no significant influence on improving water transfer during osmotic dehydration of cranberries.

In Table 1, average soluble sugar contents in °Brix of HFCS and cranberries at the start and at the end of experiment, as well as the initial and final moisture contents of cranberries for each method are presented. It can be observed from Table 1, that it is possible to obtain with appropriate osmotic dehydration treatment almost 50% of moisture loss from 88% of initial moisture to 44.7% of final moisture in the method with 65°C and 180 s. But, the most important parameters for determination of effectiveness for the aforementioned methods are the three parameters: mass gain, solids gain, and moisture loss. Their change can be seen in Table 2.

Higher moisture loss for standard (50.6%) than for any of the chemically treated samples was not statistically significant, and this study confirmed the results from similar experiments by Beaudry (2001); chemical pretreatment has no significant influence on quantitative parameters that describe water exchange between osmotic agent and fruit. The majority of parameters had similar results as the standard sample (no chemical pretreatment). Therefore, in further experiments within this study, chemical treatment was not used.

Mechanical pretreatment The purpose of this method was to increase the available surface for water to depart from a produce. There are several methods of mechanical pretreatment, but only two were tested here, cutting into halves and cutting into quarters with a stainless steel knife. These methods were compared with the standard (whole berries, with intact skin).

Table 2. Change in mass gain, solids gain, and moisture loss of cranberries treated with different chemical methods and osmotically dehydrated under similar conditions.

Chemical pretreatment		Parameters observed		
Temperature (°C)	Time (s)	Mass gain (%)	Solids gain (%)	Moisture loss (%)
23	60	7.0 a	32.9 c	47.1 b,c
	180	5.6 a	45.1 a,b	47.8 a,b
45	60	9.0 a	41.7 a,b	42.4 d
	180	17.5 b	48.1 a,b	44.5 c,d
65	60	4.5 a	45.3 a,b	48.6 a,b
	180	14.5 b	51.3 a	46.7 b,c
Standard (no chemical pretreatment)		5.2 a	47.8 a,b	50.6 a

Duncan groupings: Means with the same letters are not significantly different.

Table 3. Average change in sugar content and moisture content for mechanically treated and osmotically dehydrated cranberries under the same conditions.

Mechanical pretreatment	Sugar (° Brix)				Moisture (% , wb)	
	Cranberries		HFCS		Initial	Final
	Initial	Final	Initial	Final		
Cutting into halves	6.0	32.5 b	77.0	58.0 c	88.0	59.8 a
Cutting into quarters	6.0	52.3 a	77.0	66.4 b	88.0	43.5 c
Standard (whole berries)	6.0	6.0 c	77.0	77.0 a	88.0	88.0 a

Duncan groupings: Means with the same letters are not significantly different.

Table 4. Change in mass loss, solids gain, and moisture loss of cranberries treated with different mechanical methods and osmotically dehydrated under the same conditions.

Mechanical pretreatment	Parameters observed		
	Mass gain (%)	Solids gain (%)	Moisture loss (%)
Cutting into halves	-4.2 a	27.4 b	31.8 b
Cutting into quarters	5.2 b	47.8 a	50.6 a
Standard (whole berries)	0.0 a	0.0 c	0.0 c

Duncan groupings: Means with the same letters are not significantly different.

The reason why only two methods were tested here is because a similar study was performed by Beaudry (2001), and it was determined that cutting into halves has significant difference compared to skin surface abrasion and puncturing the skin with a needle. Therefore, cutting of the berry into halves was tested against cutting into quarters, for the same observed

parameters. All other conditions were identical: no chemical pretreatment, osmotic dehydration in HFCS (sugar to fruit mass ratio 2:1) for 24 hours at room temperature (23°C).

The initial and final Brix degree of cranberries and HFCS, as well as moisture content of cranberries can be seen in Table 3. No change was noticed to the standard, meaning that no mass transfer had occurred. Cutting into quarters showed significant difference when compared to cutting into halves for all three parameters.

Table 4 confirms that mechanical pretreatment has significant influence on water transfer, and that cranberries cut in quarters have maximum "active" surface for water and sugar exchange. This method offers the highest mass gain, the highest solids (sugar) gain, and most importantly, the highest moisture loss; over 50% of the initial moisture was removed in osmotic dehydration, reducing initial moisture content from 88% to a final 43.4%.

The parameter "solids gain" is especially important for sour fruits such as cranberries, because their tart taste is an obstacle for fresh consumption; they have to be processed, or, as in this case, sweetened. Its values can be found in Tables 2, 4, and 7.

Mechanical pretreatment results confirmed previous studies from Beaudry (2001) and Venkatachalapathy (1998) that this method is very important and can have a big influence in subsequent drying, both from fruit quality and process economics points of view. Two tested levels, cutting into halves and into quarters, demonstrated significant difference and thus mechanical pretreatment of cutting into quarters was used in subsequent experiments within this study.

Osmotic dehydration

Osmotic dehydration time Time of osmotic dehydration had a significant effect on observed parameters (Table 5 and Fig. 1).

Time has a significant effect on solids gain (sugar uptake) and moisture loss; while for the mass gain, time has no effect. However, considering that moisture loss is the most significant parameter of these three, and that osmotic dehydration for 24 hours had the highest percentage of moisture loss, this time of 24 hours is recommended for subsequent experiments.

Table 5. Average change in sugar content and moisture content for cranberries at different times of osmotic dehydration (HFCS 2:1)

Time of osmotic dehydration (h)	Sugar (° Brix)				Moisture (% wb)	
	Cranberries		HFCS		Initial	Final
	Initial	Final	Initial	Final		
12	6.0	42.6 b	77.0	61.6 c	88.0	53.6 a
24	6.0	52.3 a	77.0	66.4 a	88.0	43.5 c
36	6.0	50.2 a	77.0	63.1 b	88.0	45.8 b
48	6.0	54.7 a	77.0	64.1 b	88.0	41.4 d

Duncan groupings: Means with the same letters are not significantly different.

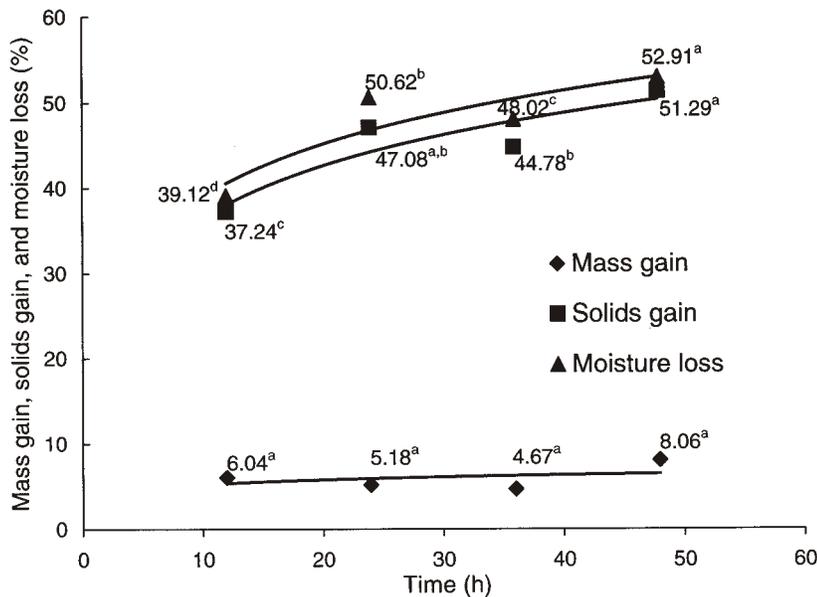


Fig. 1. Average change in mass gain, solids gain, and moisture loss in time for osmotic dehydration during dehydration with HFCS, 2:1 mass ratio HFCS to fruit. Duncan groupings: Means with the same letters are not significantly different.

Table 6. Average change in sugar content and moisture content for cranberries with different osmotic agent and its concentration during treatment of 24 hours.

Osmotic agent		Sugar (° Brix)				Moisture (% wb)	
Type	Mass ratio	Cranberries		HFCS		Initial	Final
		Initial	Final	Initial	Final		
Sucrose	1:1	6.0	35.0 c	NA	NA	88.0	51.9 c
	2:1	6.0	36.0 c	NA	NA	88.0	52.5 c
	3:1	6.0	23.5 d	NA	NA	88.0	58.9 b
	4:1	6.0	23.2 d	NA	NA	88.0	64.3 a
HFCS	1:1	6.0	43.5 b	77.0	52.5 b	88.0	52.4 c
	2:1	6.0	52.3 a	77.0	66.4 a	88.0	43.5 d

Duncan groupings: Means with the same letters are not significantly different.

There is also another very important factor to consider: with respect to quality, samples subjected to longer duration (>24 h) became darker which was visible by the naked eye, and emitted an unpleasant odour, but the samples treated for 24 hours did not show these changes.

Osmotic agent type and its concentration

Table 6 shows initial and final average values of Brix content for cranberries and HFCS (where applicable), as well as moisture content.

The noticeable advantages of HFCS as an osmotic agent over granular sucrose can be seen in Table 7. Significantly higher moisture loss and solids (sugar) gain for HFCS are a considerable advantage of this osmotic agent. There are many reasons that can explain this, such as higher mobility of viscous liquid HFCS compared to solid crystals of granular sugar. Another reason may also be that the essential component in granular sugar is sucrose (disaccharide) and in HFCS, fructose (monosaccharide). The size of a molecule may also have an influence on the permeability and mobility of the molecule. This is confirmed in works of Karathanos and Kostaropoulos (1995) and Lerici et al. (1985). In both studies the advantage of monosaccharide (glucose or fructose, respectively) against disaccharide (sucrose in both experiments) was proven. Argaiz et al. (1994) determined that glucose, which has low molecular weight, has a more profound effect on water activity depression than polysaccharides (sucrose, maltodextrines) at identical moisture content. Contreras and Smyrl (1981) concluded that the solid uptake is inversely correlated with the size of the molecule of the osmotic agent.

Mass ratio of agent to fruit also had significant influence on osmotic dehydration. As expected, higher ratio offered higher moisture removal and higher sugar uptake for HFCS, but this was not the case with sucrose. Higher ratio of sugar to fruit caused unanticipated results; lower moisture loss and higher mass loss. One possible reason for this phenomenon could be a totally different mass transport mechanism occurring for granular sugar to cranberries when compared to the mechanism occurring during mass exchange between liquid HFCS and cranberries.

Table 7. Average values of mass gain, solids gain, and moisture loss for osmotically dehydrated cranberries using different osmotic agent type and concentration.

Osmotic agent		Parameters observed		
Type	Mass ratio	Mass gain (%)	Solids gain (%)	Moisture loss (%)
Sucrose	1:1	-15.7 c	28.7 c	41.0 b
	2:1	-9.2 c	31.2 c	40.4 b
	3:1	-25.4 b	18.8 d	33.1 c
	4:1	-47.7 a	6.7 e	26.9 d
HFCS	1:1	3.0 d	37.0 b	40.4 b
	2:1	5.2 d	47.8 a	50.6 a

Duncan groupings: Means with the same letters are not significantly different.

Osmotic dehydration, as the most influential pretreatment on the water removal process, needs to be tested in more detail. Three factors (duration of process, agent type, and concentration) were tested with multiple levels. All three aspects had significant effects on the osmotic dehydration process at a significance level of 0.05. One combination can be selected as optimal based on observed parameters, osmotic dehydration for 24 hours, HFCS as osmotic agent, and concentration of 2:1 (mass ratio of HFCS to fruit).

CONCLUSIONS

Different methods of pretreatment can have significant influence on subsequent drying processes. In this research, several techniques of pretreatment with various levels were tested one against another. The effect of different pretreatments can be summarised as:

1. Chemical pretreatment parameters (time and temperature of reaction) had no significant influence on mass transfer.
2. Mechanical pretreatment showed substantial increase in moisture loss and sugar uptake, because the "active" surface area for mass transfer is greater.
3. All three factors of osmotic dehydration (process duration, agent type, and concentration of sugar solution) showed significant influence.

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