

## Drying of Sliced Vegetables Pretreated With Sugar Solutions

Sachie FUJII<sup>1</sup>, Noriko YOSHIMOTO<sup>1</sup>, Turkan AKTAS<sup>2</sup>, Shuichi YAMAMOTO<sup>1</sup>

<sup>1</sup> Bio-Process Engineering Laboratory, Yamaguchi University, Ube, 755-8611-JAPAN

<sup>2</sup> Department of Agricultural Machinery, Namik Kemal University, Tekirdag-TURKEY  
shuichi@yamaguchi-u.ac.jp

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**Abstract:** Steam blanching (3-4 minutes) followed by soaking into trehalose-maltosyltrehalose mixture solutions for 10 minutes was found to be a very effective pretreatment method for drying of sliced vegetables (potatoes and carrots). Peroxydase measurements showed that the enzyme activity was completely inactivated by a 3-minute steam blanching. Blanched samples were soaked in a 20 wt% (weight percent) sugar solution for 10 minutes at room temperature, and then dried by hot-air drying at 303K. The dried product with sugar solution treatment resulted in good product properties such as less shrinkage or deformation and better colorness retention. Especially, a solution composed of 18wt% trehalose and 2wt% maltosyltrehalose was quite effective in terms of the product quality and the drying efficiency.

**Key words:** Drying, sugar solutions, water activity, vegetables, trehalose

### INTRODUCTION

As pretreatment is essential for drying of vegetables various different pretreatment methods have been used (Latapi and Barrett, 2006). Among them, blanching is quite frequently employed mainly in order to inactivate enzymes, which cause unwanted product quality changes such as enzymatic browning. After the blanching products to be dried are dipped in a solution such as potassium meta bisulphate or ascorbic acid.

Blanching may increase the drying rate of products presumably due to partial cell wall destructions. However, in some cases blanching does not increase the drying rate because of starch gelatinization that results in reduced porosity.

The higher drying rate of samples frozen prior to drying is because freezing causes cell disruption, which allows moisture to be removed more easily

We have found that a pretreatment method which includes blanching followed by sugar treatment is promising and attractive as it is safe and does not change the food texture and quality significantly (Aktas et al., 2004;2007). Trehalose is a well-known sugar, which can stabilize various food components such as proteins. We have developed an improved method for drying sliced vegetables with a trehalose-pretreatment (Aktas et al., 2004;2007). In this method, sliced

vegetables (potatoes and carrots) were blanched and then soaked in a trehalose solution before drying. The dried sliced vegetables showed much better qualities such as negligible shrinkage and less color changes.

One of the problems in this method is that trehalose tends to form crystals in the dried products, which is not favored. In order to avoid such crystal formations we examined the effect of addition of oligo-saccharides (maltosyltrehalose) into a trehalose solution. The isothermal drying experiments as well as the desorption isotherm measurement experiments were carried out as a function of trehalose/ maltosyltrehalose ratio in order to examine solid phase or crystal formation during drying. Peroxidase activity was measured to confirm the effectiveness of steam blanching. Different sugar solutions in addition to trehalose and maltosyltrehalose were employed as a pretreatment solution. Isothermal drying of sliced vegetables (potatoes and carrots) were carried out and both the drying curve and the dried product appearance were examined carefully.

### MATERIALS and METHODS

#### Materials

Vegetables (potato and carrot) were purchased at a local shop. They were washed under running water,

wiped with blotting paper, hand-peeled and sliced using a manual slicer. The sliced samples were then cut in 20 mm diameter by means of a sampler having a sharp edge (20 mm diameter). The thickness of sliced samples was 1, 1.5 or 2mm, which was checked by using a digital linear gauge.

Sugars employed in this study are trehalose (Trehalose, Hayashibara, Japan), maltodextrin (dextrose equivalents DE=11, Pinedex #2, Matsutani Kagaku Kogyo, Japan), sucrose and maltosyltrehalose - rich syrup (Hallodex, Hayashibara, Japan). This syrup contains 52% of maltosyltrehalose and the DE value is ca.14. Maltosyl trehalose (C<sub>24</sub>H<sub>42</sub>O<sub>21</sub>, mol.wt 666) is a non-reducing tetrasaccharide, in which maltose is linked to trehalose. Trehalose (C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>, mol.wt 342) is also non-reducing disaccharide, which usually exists as the dehydrate.

#### Pretreatments

Steam was applied for 3 minutes for carrot, 4 minutes for potato as blanching based on the peroxidase inactivation experimental data and the texture of the sample (see Fig.1).

A 20 wt% (weight %) sugar solution was used for pre-treatment process. Steam blanched samples were cooled, drained and wiped with blotting papers. Then, they were soaked in a sugar solution for 10 minutes at room temperature before the drying experiment.

#### Peroxidase activity measurement

1wt % guaiacol and 1wt% H<sub>2</sub>O<sub>2</sub> solutions were dropped onto the surface of sliced vegetable samples (ca. 1 mL), and then the appearance after 5 minutes was captured by a digital camera.

#### Desorption isotherm

Samples were stored in a sealed container in the presence of saturated salt solutions of known water activities ( $A_w$ ). A constant temperature and humidity chamber (Enviros, KCL-1000, EYELA, Japan) was also employed for the measurement.

The samples were weighed periodically. It is not easy to confirm the equilibrium of these samples as they change the physical properties with time (i.e., crystallization, rubber-glass transition, etc.). So we decided to terminate the experiment when the weight loss became less than 2% per 12 hours (usually two to three days).

The isotherm data were fitted by a three parameter Guggenheim-Anderson -de Boer (GAB) model (Rahman, 1995 Timmermann, 2003).

$$X = \frac{CKA_w W_m}{(1 - CKA_w)(1 - KA_w + CKA_w)} \quad (1)$$

$X$  is the water content.  $W_m$  implies the water content equivalent to a monolayer coverage.  $C$  and  $K$  are constants related to the binding energies.

#### Drying experiments

Isothermal drying experiments were performed in a constant-air temperature box. Silica gels or saturated salt solutions were placed in the box to control the relative humidity (RH). The air temperature was controlled so that the sample temperature is maintained at an assigned temperature. The air temperature in the drying box was somewhat higher than the assigned value at the beginning of the experiment, and then, lowered gradually with the progress of the drying. The weight and the temperature measurements were done separately

## RESULTS and DISCUSSION

#### Effect of blanching on peroxidase inactivation

Figure 1 shows the effect of blanching time on peroxidase inactivation. It is clear that steam blanching for three minutes completely inactivate peroxidase. Therefore, steam blanching for 3 minutes was chosen as the blanching condition.

#### Desorption isotherm

Figures 2 and 3 show the desorption isotherm of trehalose and maltosyltrehalose (MT) -rich syrup (Hallodex), respectively. Trehalose solutions formed crystals after one day and the equilibrium water content is equal to that of trehalose-dihydrate irrespective of water activity ( $X=0.11$ ).

On the other hand, the shape of the desorption isotherm of Hallodex is quite similar to a typical food isotherm. The GAB parameter values were close to those of maltodextrin (Yamamoto et al., 2004; 2005; Aktas et al., 2007a ). This is not surprising as the DE of the two sugars are almost the same.

When Hallodex was added to trehalose, the formation of crystals was inhibited (Fig.4). When the

Hallodex content is above 0.1 (kg- Hallodex /kg-total sugar), no crystals were observed and the sample was transparent even at low equilibrium moisture contents. The isotherm was similar to that of Hallodex.

Isothermal drying experiments with a trehalose-Hallodex mixture showed that when Hallodex content was ca 10 wt% of the total sugar weight, solid phase was not observed. The sample was transparent until the end of the drying. The drying curve was almost superimposable to that for Hallodex solution. The isotherm data and the drying data indicate that a trehalose-Hallodex mixture is suited as a pretreatment solution for sliced vegetable drying as the crystals may not appear on the dried product surface.

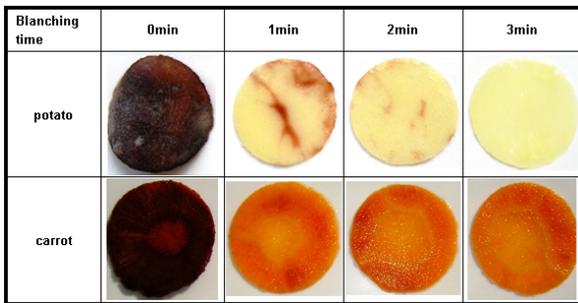
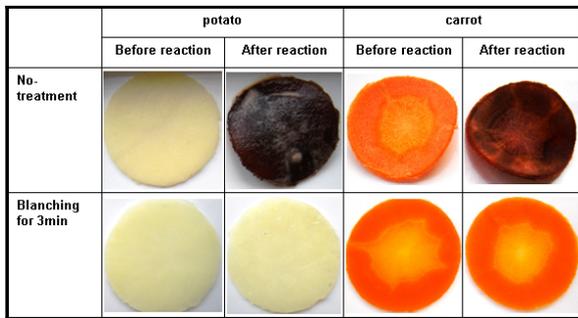


Figure 1. Effect of blanching time on peroxidase inactivation

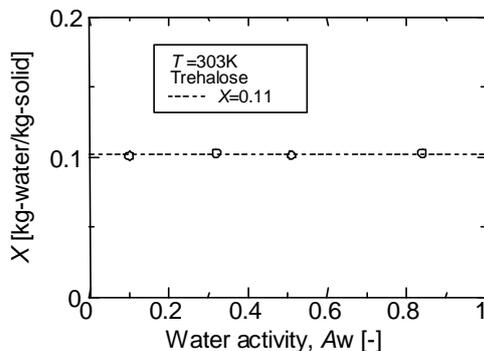


Figure 2. Desorption isotherm of trehalose

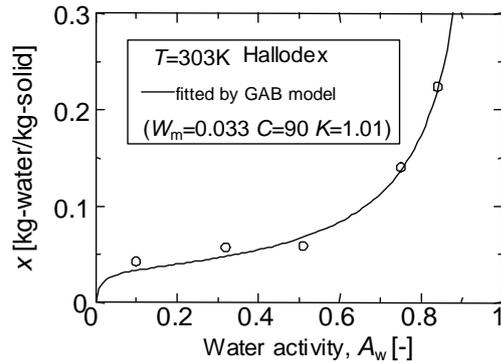


Figure 3. Desorption isotherm of maltosyltrehalose-rich syrup (Hallodex)

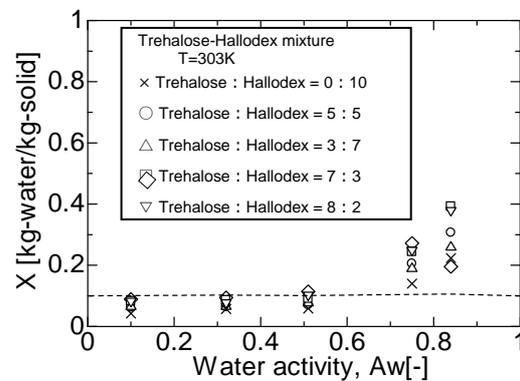


Figure 4. Desorption isotherm of Hallodex (maltosyltrehalose-rich syrup)-trehalose mixture.

### Drying experiment

Isothermal drying experiments at 303K were carried out for sliced potato samples with different pretreatment procedures. As shown in Fig.5, the drying curves are different. With sugar solution pretreatment the sample was pre-dehydrated due to osmotic dehydration. The drying curve with the Hallodex pretreatment shows much higher drying rate compared with others especially at the beginning of the drying experiment. On the other hand, the drying curve with trehalose shows very low drying rates at later stage of drying where the average water content  $X$  is below 0.2.

The appearance of the dried product with different pretreatment procedures is shown in Fig.6. Without any pretreatments potato samples showed quite significant irregular shrinkage. The color is much darker compared with other samples. Blanching itself is quite effective especially for the retention of favored color. All sugar treatments after the blanching resulted in better product shape and color. The color

of the sample pretreated with trehalose is somewhat different from others. This may be due to crystallization of trehalose, which was not identified quantitatively.

Other important properties of dried products are textures, taste and flavors. Solid gain (SG) during soaking in a trehalose solution was not significant Aktas et al., (2007). The dried products pretreated with a trehalose-maltosyltrehalose mixture solution were immersed in a hot water in order to test the quality. They were still crispy and not sweet

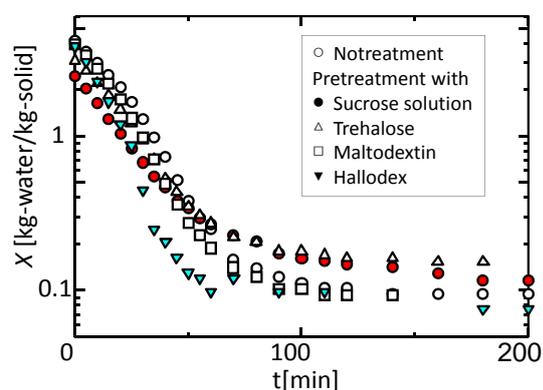


Figure 5. Drying curves of sliced potato samples with different pretreatment procedures

In order to prevent crystallization of trehalose a mixture of trehalose and Hallodex was used as a pretreatment sugar solution. As shown in Fig.4 and isothermal drying data (data not shown), this mixture can prevent crystallization of trehalose effectively.

As shown in Fig. 7, the drying curve for the trehalose-Hallodex mixture pretreatment is favorable. The drying rate is much higher at later stage of the drying ( $t > 100$  min and  $X < 0.2$ ).

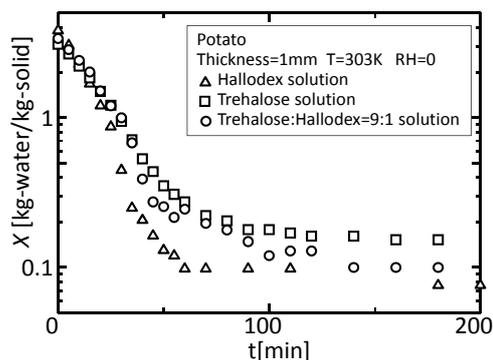


Figure 7. Drying curves of sliced potato samples with trehalose-Hallodex mixture pretreatment

## CONCLUSIONS

Effects of pretreatment methods on the drying curve and the dried product quality of sliced vegetables (potatoes and carrots) were experimentally investigated. Soaking of samples in a trehalose-maltosyltrehalose solution was found to be best suited as a pretreatment sugar solution after a three-minute steam blanching. The drying rate was accelerated with this pretreatment. The dried product showed better quality (less shrinkage and favored color).

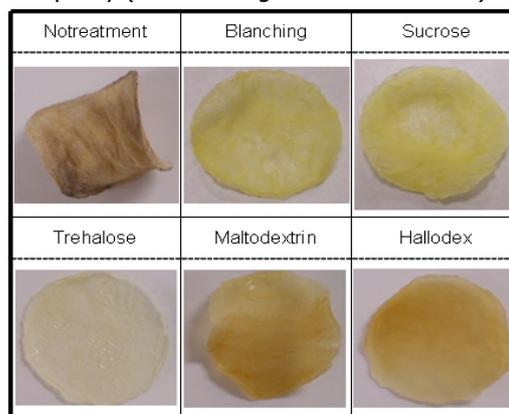


Figure 6. Appearance of dried sliced potato samples with different pretreatment procedures

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