IDS'2018 – 21st International Drying Symposium
València, Spain, 11-14 September 2018
DOI: http://dx.doi.org/10.4995/ids2018.2018.7487

Effect of saccharide additives on dehydration–drying kinetics and quality properties of dried kiwi fruit products

Ueno, S.[a*]; Iijima, R.[a]; Harada, M.[a]; Liu, H.[b]; Shimada, R.[a]; Fukami, K.[c]

[a] Faculty of Education, Saitama University, Saitama, Japan.

[b] Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan.

[c] San-ei Sucrochemical Co., Ltd. Aichi, Japan.

*E-mail of the corresponding author: shigeakiu@mail.saitama-u.ac.jp

Abstract

The effects of saccharide additives on the dehydration and drying properties as well as the quality properties of dried kiwi fruit products were investigated. Sliced kiwi fruits were soaked and dehydrated in citric acid, glucose, sucrose and the pH-adjusted sugar solutions, individually. Osmotic dehydration and drying kinetic parameters were calculated using exponential models. Drying rate constants and water activities of dried kiwi fruits with osmotic dehydration were superior to those without osmotic dehydration. Soaking solutions with a lower pH led to a decrease in lightness. However, soaking sokution pH had no significant effect on the water activity or drying kinetics.

Keywords: *drying; kinetics; kiwi fruit; osmotic dehydration*

1. Introduction

Kiwi fruit (*Actinidia deliciosa*) is a popular fruit due to its taste, cost, cooking affinity, nutrition and functional properties. Kiwi fruit is low in fat and sodium, and it is high in organic acids, vitamin C, vitamin E, folic acid, dietary fibre, potassium and polyphenols. Vitamin C, vitamin E and polyphenols show strong antioxidant activities. Additionally, many components in kiwi fruit have a positive effect on human health. Therefore, the consumption of kiwi fruit in Japan has approximately doubled in the last 10 years.

Dried fruit is known to have a long shelf life and has specific texture, taste and functional properties [1-3]. The manufacturing process of dried fruits requires a certain amount of sugar; however, consumers pay attention to their health, and dried fruits with less sugar or without sugar are more desirable. Thus, food companies in Japan have been developing new dried fruit products, such as those with lower calories.

The manufacturing process of dried fruit products involves two main procedures, osmotic dehydration and a drying process. Osmotic dehydration draws water from the fruit and adds a sweet taste by soaking the fruit in a sugar solution [4]. Osmotic dehydration also prevents colour degradation and hardening. Sugar-soaked fruits are then dried in a hot air drying oven or by sun drying. While osmotic dehydration and drying characteristics of fruits are well established [1-4], the addition of pH-adjusted saccharides has rarely been reported in osmotic dehydration and drying processes.

The objectives of this study were to investigate the effect of pH in osmotic dehydration solutions on dehydration and drying properties and to investigate the quality properties of dried kiwi fruit products.

2. Materials and Methods

2.1. Osmotic dehydration of fresh kiwi fruit

Saccharides, such as glucose, sucrose, maltose, citric acid (Wako Pure Chemical Industry, Osaka, Japan), sorbitol, erythritol (B Food Science Co., Ltd., Tokyo, Japan) and trehalose (Hayashibara, Okayama, Japan), glucose and sucrose adjusted to pH 2.0 were selected as soaking solutions for osmotic dehydration.

Fresh kiwi fruits (Zespri, New Zealand) were purchased from a local supermarket. Kiwi fruits were cut into 10-mm-wide slices and weighed. Sliced kiwi fruits were soaked in 60% (w/w) soaking solutions at 60°C for 80 min at 50 rpm in a shaking water bath (Taitec, Saitama, Japan). During soaking, kiwi fruit slices were weighed every 5 min. The kiwi fruit slices were gently wiped with paper towel after soaking.

2.2. Drying of osmotic-dehydrated kiwi fruit and kinetic analysis

After osmotic dehydration, the kiwi fruit slices were transferred to a drying oven (WFO-410W, Nakayama Rika, Saitama, Japan) and dried at 80°C for 6 h. During drying, kiwi fruits were weighed every 30 min. Based on the weight changes during drying, moisture content was calculated as the time course of the sample weight and equilibrium dry weight. Drying characteristics were evaluated by several mathematical models. The dimensionless relative moisture content against drying time was plotted as a drying curve. Utilising the drying curves of samples with different osmotic dehydration solutions, kinetic parameters of the most simplified model, known as the exponential model [4], were calculated as follows:

$$MR = (M - M_e) / (M_0 - M_e) \tag{1}$$

$$MR = \exp(-kt) \tag{2}$$

Where MR and M indicates the dimensionless relative moisture content and the certain moisture content, M_0 indicates the initial moisture content, M_e indicates the equivalent moisture content, k indicates the drying rate constant (min^{-1}) and t indicates the drying time (min). Usually, this model does not provide an accurate simulation of the drying curve for many foods, particularly by underestimating the beginning of the drying curve and overestimating the later stages [5]. Therefore, another exponential model called the Page model was also applied [5,6].

$$MR = \exp(-kt^n) \tag{3}$$

Where n indicates the empirical constant. Equations (2) and (3) were applied to the dimensionless relative moisture content during drying, and the drying rate constant k was calculated using Kaleida Graph 4.0 J (Hulinks, Tokyo, Japan).

2.3. Quality analyses of dried kiwi fruit

Several quality factors are important for both consumers and food suppliers; consumers mainly determine product quality based on the colour of dried fruit in a supermarket, while the most important factor for suppliers is the shelf life. We determined the quality of dried kiwi fruits by surface colour and water activity in this study. Colour parameter L*a*b* (L; lightness, a; green-red, b; blue-yellow) of quarter-cut dried kiwi fruits was measured using a colour metre (ZE2000, Nippon Denshoku Industry. Co. Ltd., Tokyo, Japan). Two-thirds of the cut dried kiwi fruits were fixed in a plastic pan for water activity measurements using a water activity metre (LabMaster aw, Novasina, Switzerland). All experiments were performed in quintuple, and results are presented as means ± standard deviations.

3. Results and Discussion

3.1. Colour

The colour of fresh kiwi fruit and dried kiwi fruit with or without (dried control) selected osmotic dehydration was measured (Table 1). Fresh kiwi fruit showed the lowest a* value, and fresh and dried control kiwi fruits showed higher L* values. Dried samples in which the pH was adjusted to 2.0 showed slightly lower L* and b* values compared with non-pH-adjusted samples (sucrose, pH 6.0, and glucose, pH 3.8). Dried fruits soaked in citric acid solutions showed the lowest L* and b* values and the highest a* values. Combinations of osmotic dehydration and drying processes led to a decrease in lightness. These results suggest that kiwi fruit's green pigments, such as chlorophyll a and b, melt into the soaking solution during osmotic dehydration and change during the thermal drying process, resulting in a change in the colour of dried kiwi fruits. However, colour changes in dried kiwi fruit soaked in sucrose and glucose solutions were limited, and these products would be more acceptable to consumers.

Table 1. Colour parameters of dried kiwi fruit with saccharide and pH-adjusted sugar solutions

Sample	L*	a*	b*
Fresh	48.9 ± 1.6	−6.9 ± 1.0	28.4 ± 1.5
Dried control (no sugar)	49.2 ± 2.9	1.5 ± 0.7	30.1 ± 2.0
60% sucrose, pH 6.0	47.0 ± 2.9	1.4 ± 1.0	32.1 ± 1.8
60% sucrose, pH 2.0	45.5 ± 2.8	1.6 ± 0.8	29.5 ± 1.5
60% glucose, pH 3.8	45.6 ± 3.9	1.8 ± 1.0	30.3 ± 2.7
60% glucose, pH 2.0	43.9 ± 3.0	1.6 ± 1.2	29.7 ± 1.8
6% citric acid	37.2 ± 2.5	3.8 ± 0.9	23.9 ± 2.0
60% citric acid	35.0 ± 2.6	7.9 ± 1.1	21.3 ± 2.2

3.2. Water activity

The water activity in food products is a well-known index of storability. While the water activity of dried kiwi fruit without osmotic dehydration was 0.61, those of osmotic-dehydrated samples ranged from 0.43 to 0.49 (Table 2). The shelf life of a food product at a given water activity may vary depending on the structure and composition of the food material, and spoilage is a concern. Microbial activity, enzyme reaction, browning reaction and lipid oxidation are strongly dependent on water activity. In this study, the microbial activities, such as those of bacteria, yeast and mould, and enzyme reactions were limited when the water activity ranged from 0.43 to 0.49. These results indicate that osmotic dehydration with sugar (including pH-adjusted samples) improves the shelf life.

Table 2. Water activity of dried kiwi fruit

Sample	Water activity
Dried control (no sugar)	0.61 ± 0.08
60% sucrose, pH 6.0	0.49 ± 0.02
60% sucrose, pH 2.0	0.48 ± 0.01
60% glucose, pH 3.8	0.48 ± 0.01
60% glucose, pH 2.0	0.47 ± 0.01
6% citric acid	0.47 ± 0.03
60% citric acid	0.43± 0.04

3.3. Kinetic analysis of drying

Based on the weight changes during drying, the moisture content was calculated as the time course of the sample weight and equilibrium weight. Then, the dimensionless relative moisture content against drying time was plotted as a drying curve. The most simplified model was applied to the drying curves. The lowest drying rate constant of dried kiwi fruit was observed in the control (Table 3). In contrast, osmotic-dehydrated samples showed higher values than the dried control (Table 3). The pH-adjusted dried samples had values similar to those of non-pH-adjusted samples. Moreover, dried samples with a citric acid solution showed lower values than those with sucrose or glucose.

Osmotic dehydration with saccharide solutions enhanced drying. However, the soaking solution pH did not have any apparent effect on the drying characteristics. A lower soaking solution pH would destroy the internal structures of kiwi fruit, such as membranes, and once membranes are destroyed during osmotic dehydration and drying processes, the internal structure of kiwi fruit will easily shrink. Therefore, the drying rate constants of lower pH samples did not increase compared with those without a pH adjustment.

Table 3. Drying rate constants of dried kiwi fruit

Sample	Drying rate constants (min^{-1})
Dried control (no sugar)	0.0045 ± 0.0001
60% sucrose, pH 6.0	0.0059 ± 0.0001
60% sucrose, pH 2.0	0.0062 ± 0.0005
60% glucose, pH 3.8	0.0062 ± 0.0005
60% glucose, pH 2.0	0.0063 ± 0.0001
6% citric acid	0.0055 ± 0.0001
60% citric acid	0.0058 ± 0.0007

3. Conclusions

We investigated the effects of saccharide additives on dehydration–drying kinetics and the quality properties of dried kiwi fruit. Drying rate constants and water activities of dried kiwi fruits with osmotic dehydration were superior to those without osmotic dehydration. Soaking solutions with a lower pH led to a decrease in lightness. However, soaking sokution pH had no significant effect on the water activity or drying kinetics. The combination of sugar and citric acid for a single soaking solution would enable to investigate a novel physicochemical and taste parameters. Further analysis of taste characteristics are essential for the dried fruit industry.

4. References

[1] Pan, Y.K.; Zhao, L.J.; Zhang, Y.; Chen, G.; Mujumdar, A.S.; Osmotic dehydration pretreatment in drying of fruits and vegetables. Drying Technology 2003, 21, 1101-1114.

[2] Sablamni, S.; Drying of fruits and vegetables: retention of nutritional/functional quality. Drying Technology 2006, 24, 123-125.

[3] Nijhuis, H.H.; TorringaH.M.; Muresan, S.; Yuksel, D.; Leguijt, C.; Kloek, W. Approaches to improving the quality of dried fruit and vegetables. Trends in Food Sci. Technol. 1998, 9, 13-20.

[4] Talens, P.; Escriche, I.; Martinez-Navarrete, N.; Ciralt, A. Influence of osmotic dehydration and freezing on the volatile profile of kiwi fruit. Food Res. Int. 2003, 36, 635-643.

[5] Simal, S.; Femenia, A.; Garau, M.C.; Rossello, C. Use of exponential, Page's and diffusional models to simulate the drying kinetics of kiwi fruit. J. Food Eng. 2005, 66, 323-328.

[6] Ueno, S.; Shigematsu, T.; Karo, M.; Hayashi, M.; Fujii, T. Effects of high hydrostatic pressure on water absorption of adzuki beans. Foods 2015, 4, 148-158.