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# Effect of starch retrogradation on texture of potato chips produced by low-pressure superheated steam drying

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ABSTRACT

The effects of the degree of starch retrogradation, initial slice thickness and final moisture content on the texture of potato chips dried by low-pressure superheated steam drying (LPSSD) were investigated in this study. Potato slices of different initial thicknesses (1.5, 2.5 and 3.5 mm) were pretreated with three different methods (blanching and then freezing for 24 h, blanching and then repeated freezing/thawing either for 3 or 5 cycles) to study the effects of these pretreatment methods on the degree of starch retrogradation. The potato slices were then dried by LPSSD at 90 °C and absolute pressure of 7 kPa to three levels of final moisture content (1.5%, 2.5% and 3.5% (d.b.)) to investigate the drying kinetics and the quality of dried potato chips in terms of hardness, toughness and crispness as well as degree of crystallinity by X-ray diffraction technique. The various pretreatment methods were found to have an obvious effect on the rates of moisture reduction of the samples. Higher degrees of starch retrogradation led to an increase in the hardness and toughness of dried chips, but did not show any significant effect on the crispness of the chips. An increase in the degree of starch retrogradation led to higher degree of crystallinity of dried potato chips.



## 1. Introduction

Potato chips are generally dehydrated by deep fat frying to a moisture content of 0.02 kg/kg (d.b.) or less. Potato chips have oil content that ranges from 35% to 45% (w.b.) (Garayo and Moreira, 2002). Due to the high level of oil as well as to an increased demand of consumers for health snack, a technique to produce potato chips without oil is required. Drying may thus be an option for the production of fat-free potato chips with the desired color and texture characteristics.

Most of the research efforts have focused on hot air drying of potato pieces of various shapes (e.g., Wang and Brennan, 1995; McMinn and Magee, 1996; Krokida, Tsami and Maroulis, 1998). However, there are many problems with hot air drying such as slow drying rate, poor product color, product deformation and substantial degradation of nutrients. Therefore, a novel concept of low-pressure superheated steam drying (LPSSD) has been proposed as an alternative to dry heat-sensitive products (Devahastin et al., 2004) since it can combine the advantages of drying at reduced temperature and pressure with those of conventional atmospheric-pressure superheated steam drying such as the ability to yield product with higher porosity, less shrinkage and better color (Mujumdar and Devahastin, 2000; Devahastin and Suvarnakuta, 2004).

Recently, LPSSD has also been applied to produce fat-free potato chips. Leeratanarak et al. (2006) studied the drying kinetics and quality of potato chips produced by LPSSD and hot air drying. It was found that LPSSD produced potato chips of better quality than did hot air drying by lowering the chips browning index. LPSSD at 90 °C was proposed as the most favorable condition for baking potato chips in their work. However, the best condition proposed still led to chips of much inferior quality compared with commercially available chips, especially in terms of texture (hardness).

To further improve the quality of potato chips, various pretreatment methods have been proposed and tested prior to LPSSD. Pimpaporn et al. (2007) studied the influences of various pretreatment methods on the low-pressure superheated steam drying kinetics and quality of dried potato chips in terms of color, texture and microstructure. The effects of blanching, combined blanching and freezing and blanching followed by immersion in chemical solutions, namely, glycerol and monoglyceride, at different concentrations and then freezing were investigated. Drying was performed at 70, 80 and 90 °C. It was found that combined blanching and freezing was the most appropriate method of pretreatment for producing good quality potato chips. This was probably due to the

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effects of starch gelatinization and retrogradation that occurred during blanching and freezing, respectively. Potato slices pretreated by blanching and freezing, then dried by LPSSD, were found to have potential to compete with deep fat fried chips.

Many studies have indeed been conducted to study the effect of starch retrogradation on physical changes of various products including potato. Radley (1976) reported that repeated freezing/thawing cycles involving subjecting samples to repeated freezing and intermittent thawing to room temperature are known to accelerate retrogradation. This is due to the fact that when starch pastes are frozen, phase separation occurs with the formation of ice crystals. Upon thawing the pastes are composed of a starch-rich and a starch-deficient aqueous phase. The extent of phase separation increases with additional freezing/thawing cycles due to an increase in retrogradation in the starch-rich phase. O'Leary et al. (2000) studied the effect of freezing/chilling on the quality of ready-meal components such as instant mashed potato, steamed salmon and steamed broccoli. In the case of instant mashed potato, freezing/chilling was found to reduce the softness, adhesiveness, whiteness and vitamin C content of the samples. The fresh sample was the softest, while the samples that had been frozen and thawed were firmer. This is most probably due to the effect of freezing, which could lead to starch retrogradation and textural changes.

The aim of this work was to further investigate the effect of the degree of starch retrogradation on the texture of potato chips dried by LPSSD. In addition, the effects of initial slice thickness and final moisture content on the texture of the chips were also investigated.

## 2. Materials and methods

### 2.1. Experimental set-up

A schematic diagram of the low-pressure superheated steam dryer and its accessories is shown in Fig. 1. The dryer consists of a stainless steel drying chamber with inner dimensions of $45 \times 45 \times 45$ cm; a steam reservoir, which received steam from a boiler and maintained its pressure at around 200 kPa (gauge); and a liquid ring vacuum pump (Nash, model ET32030, Trumball, CT), which was used to maintain vacuum in the drying chamber. Steam trap was installed to reduce excess steam condensation in the reservoir. An electric heater, rated at 1.5 kW, which was controlled by a proportional-integral-derivative (PID) controller (Omron, model E5CN, Tokyo, Japan) was installed in the drying chamber to control the steam temperature and to minimize condensation of steam in the drying chamber during the start-up period. Two variable-speed electric fans were used to disperse the steam throughout the drying chamber. The sample holder was made of a stainless steel screen with dimensions of $16.5 \times 16.5$ cm. The change of the mass of the sample was detected continuously (at 60 s interval) using a load cell (Minebea, model Ucg-3 kg, Nagano, Japan), which was installed in a smaller chamber connected to the drying chamber by a flexible hose (in order to maintain the same vacuum pressure as that in the drying chamber), and also to an indicator and recorder (AND A&D Co., model AD4329, Tokyo, Japan). For detailed experimental set-up the reader is referred to Devahastin et al. (2004).

### 2.2. Materials

Fresh potato (*Solanum tuberosum*) was purchased from a local market and stored at 4 °C. Prior to each experiment, potato was washed with tap water to remove dirt and soil from its skin. After that potato was peeled and sliced to three levels of initial thickness (1.5, 2.5, and 3.5 mm) by an electric slicer. The potato slices were then shaped using a core borer to a diameter of 45 mm.

### 2.3. Methods

The sliced potato was blanched in hot water at 90 ± 2 °C for 5 min with the ratio of potato to water of 0.015 g/g (Leeratanarak et al., 2006). The samples were immediately cooled in cold water (4 °C) and placed on paper towel to remove excess water.

The samples were subjected to three different pretreatment methods to investigate the effect of starch retrogradation on the texture of dried potato chips. First, the samples were pretreated by blanching and then freezing at −20 °C in a chest freezer (Sanyo, Model SF-C-65, Tokyo, Japan) for 24 h (or 48 and 72 h in the preliminary experiments to determine the effect of freezing time on the degree of retrogradation of starch granules in potato). Second, blanched potato was frozen in the chest freezer at −20 °C for 24 h and then thawed at 30 °C for 1 h; the whole process was repeated for 3 cycles. Finally, blanched potato was frozen and thawed at the above-mentioned conditions for 5 cycles. The samples were then baked by LPSSD at 90 °C and absolute pressure of 7 kPa (Leeratanarak et al., 2006) to three levels of final moisture content (1.5%, 2.5% and 3.5%); 6 slices of potato were used in each drying experiment. The samples were placed horizontally on the tray. Since the drying chamber was heated prior to the start of each experiment, the effect of initial condensation was negligible (Devahastin et al., 2004). The moisture content of the samples was determined using the vacuum oven method (AOAC, 1984).

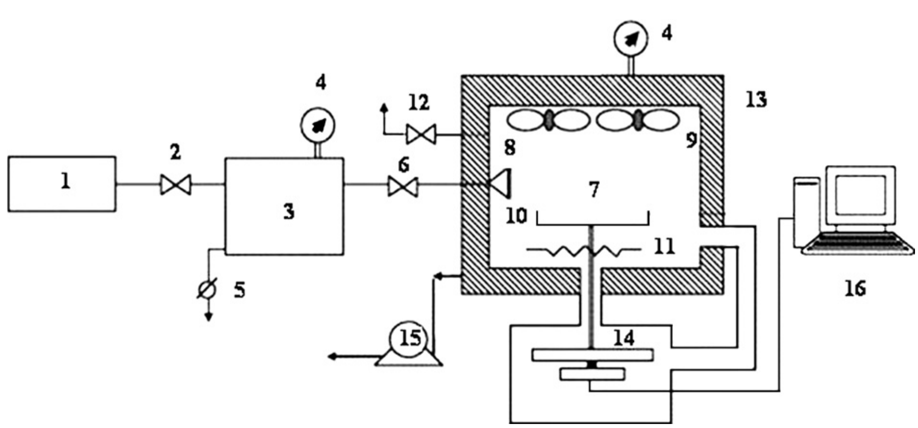


**Fig. 1.** A schematic diagram of low-pressure superheated steam dryer and associated units. (1) boiler; (2) steam valve; (3) steam reservoir; (4) pressure gauge; (5) steam trap; (6) steam regulator; (7) drying chamber; (8) steam inlet and distributor; (9) two electric fans; (10) sample holder; (11) electric heater; (12) vacuum break-up valve; (13) insulator; (14) on-line mass indicator and logger; (15) vacuum pump; (16) PC with installed data acquisition card.