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Research note

Effect of temperature fluctuations on ice-crystal growth in frozen potatoes during storage

Javid Ullah [a], Pawan S. Takhar [a, *, 1], Shyam S. Sablani [b]

[a] Food Science and Human Nutrition, University of Illinois at Urbana Champaign, USA
[b] Biological Systems Engineering, Washington State University, Pullman, WA, USA

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ABSTRACT

Temperature fluctuation during storage and distribution of frozen foods has been a major concern for frozen food manufacturing industry. The fluctuation of temperature results in thawing and recrystallization of ice crystals, which is the main cause of frozen food quality degradation during storage. The effect of temperature fluctuations on ice recrystallization in frozen potatoes was investigated. Using micro computed tomography, growth in pore area due to increase in ice crystal sizes was determined. Four treatments (constant at −80 °C; and fluctuations between −17 to −16 °C, −17 to −11 °C and −17 to −7 °C) were used to observe their effect on pore size distribution. The growth of ice crystals with the increase in amplitude of temperature fluctuations resulted in damaging the microstructure of frozen potatoes. The damage pore solid walls resulted in reduction of the number of pores and increase in the size of pores.

1. Introduction

Potato is a starchy tuberous crop, known as *Solanum tuberosum*, belonging to the family Solanaceae. For centuries potatoes have been consumed and have become an integral part of food globally. After rice, wheat and maize, potato is the next important food crop. More than 30% of the potato crop is used for making French fries worldwide (Saguy & Pinthus, 1995). For more than one and a half century potato chips have been a popular snack in the US and its retail sale is about $6 billion/year, which is 33% of the total sale in the market (Garayo & Moreira, 2002). For longer storage, potatoes require specialized care in stores. If potatoes are held for several days at 4.5 °C, or below, reducing sugars accumulate, resulting in dark color of processed product (Talburt & Smith, 1959). Temperature above 24 °C for long periods of time may increase certain types of storage rot diseases and, in fairly airtight areas, may result in blackheart, a discolored break down of the tissues in or near the center of the tuber. Fluctuation in transit temperature may cause potatoes to be unacceptable at their destination due to accumulation of reducing sugars to amounts, which result in chips of dark color. Storage has multiple effects on potatoes sugar content, starch, enzymes, respiration and organic acids. It is difficult to maintain raw potato quality during storage. On the other hand French fries and dehydrated potatoes are somewhat less susceptible to browning (Talburt & Smith, 1959).

Freezing and thawing may result in textural changes of frozen foods during storage and transportation due to the growth in size of ice crystals. The rate of growth in crystal size depends upon fluctuation of temperature during storage and transportation. Small ice crystals are formed during quick freezing, which are unstable during freeze/thaw operations. The small ice crystals become larger in size resulting in more stable crystals during storage (Ablett, Clarke, Izzard, & Martin, 2002; Adapa, Schmidt, Jeon, Herald, & Flores, 2000; Chevalier, Le Bail, & Ghoul, 2000; Do, Sagara, Tabata, Kudoh, & Higuchi, 2004; Hagiwara, Hartel, & Matsukawa, 2006). The advantage of quick freezing may attenuate by fluctuation of storage temperature resulting in state and phase transition. Foods are considered to be more stable in their glassy state, in which their molecular motion is reduced. Reduced molecular motion helps to maintain food quality. The transition of food from glassy to rubbery state and vice versa is unavoidable under freeze/thaw conditions. The increased molecular mobility in rubbery state results in the enlargement of crystals and subsequent quality degradation (Syamaladevi, Kalehiwot, Balasigam, & Sablani, 2012). Glassy and rubbery states are important in frozen foods as the reactions are reduced to a large extent in the glassy state (Hagiwara, Mao, Suzuki, & Takai, 2005; Syamaladevi, Sablani, Tang, Powers, &

* Corresponding author.
E-mail address: ptakhar@illinois.edu (P.S. Takhar).
[1] Author has previously published as Pawan P. Singh.

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Swanson, 2010). The effect of freezing and thawing during storage has also been studied in meat, sea foods, ice cream and sugar solutions, which causes undesirable changes in texture of food (Adapa et al. 2000; Hagiwara et al. 2006; Mousavi, Miri, Cox, & Fryer, 2007; Syamaladevi et al., 2012).

The X-ray micro computed tomography system allows visualization and measurement of complete three dimensional object structures with minimal sample preparation. The techniques have been used for many materials such as rocks, bones, ceramics, metals (Salvo et al., 2003), and food proteins (Mousavi, Miri, Cox, & Fryer, 2005; Mousavi et al., 2007). The approach of CT scanning has also been used for fresh fruits (Lin et al., 2008), for measuring distribution of fat in beef muscles (Frisullo, Marino, Laverse, Albenzio, & Del Nobile, 2010) and other food materials (Lida, Matsuoka, Shimizu, Wakisaka, & Katsumata, 2013). This communication discusses the effect of fluctuating storage temperature on microstructural changes in potatoes due to ice recrystallization. While freeze/thaw studies have been performed in the past, this manuscript's emphasis is on quantifying the porous microstructure formation due to recrystallization by performing image analysis. The quantitative analysis discussed in the study will be useful for engineers designing the freezing operation and in future studies aimed at modeling the freeze/thaw process. The results will also help food industries in maintaining food quality during storage and transportation by understanding the effect of temperature fluctuations during storage and shipping on crystal formation and growth.

2. Materials and methods

Fresh potatoes (*Russet var.*) were purchased from a local grocery store. The potatoes were cut to French fry cuboid shapes (11.9 mm × 11.9 mm × 63.5 mm). The cut potatoes were washed with fresh tap water to remove starch from the surface to avoid

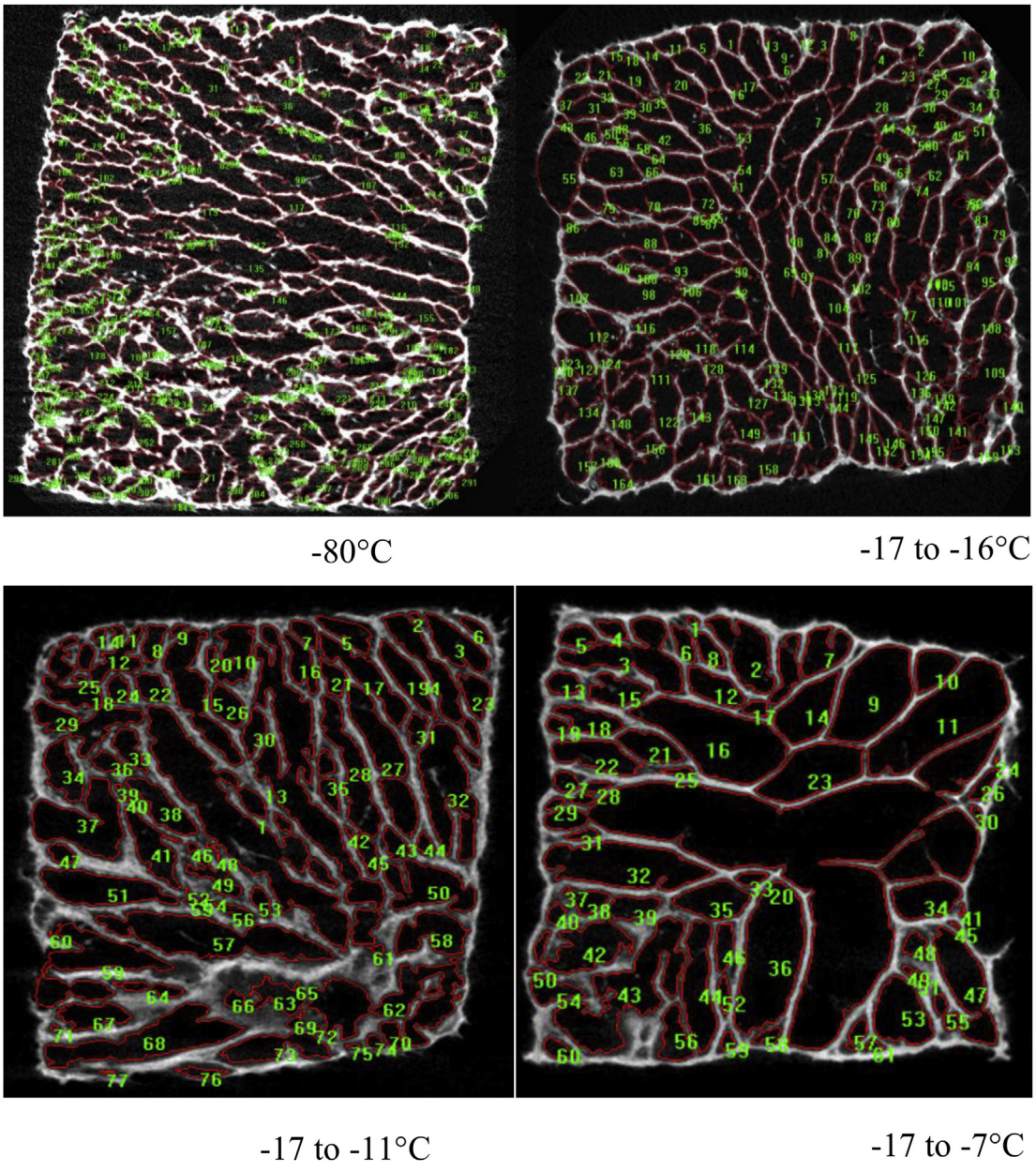

Fig. 1. CT scan micrographs of freeze dried potatoes showing the pores sizes as a function of fluctuation in freezing temperature.