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Changes in the textural and thermal properties of batter coated fried potato strips during post frying holding

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ABSTRACT

Post frying conditions play a very important role in consumer acceptability of French fries. During post frying holding time, from when fried potatoes are removed from a fryer to when consumed, texture of the product dramatically changes. Therefore, it is important to understand how and why these changes happen. In this study, the effect of different batter formulations and post frying holding time (with and without using a heat lamp) on fat and moisture distribution, textural and thermal properties of fried potato strips was studied. Moisture content ranged from 3.90 to 5.32 (in core region), 0.54 to 1.19 (in crust region), and 1.96 to 2.89 g/g db (in whole potato strips). Fat content of the core, crust and whole potato strip regions ranged between 0.01–0.03, 0.14–0.25, and 0.07–0.15 g/g db, respectively. A slight migration of moisture from the core to crust regions was observed under heat lamp holding, but this did not affect the total moisture content. Potato samples that were not kept under heat lamp showed lower hardness than samples kept under heat lamp. Brittleness values of potato samples increased from 0 to 10 min heat lamp duration and after that it significantly decreased. It was found that glass transition temperature of the samples was also affected by batter formulation and heat lamp duration.

1. Introduction

Health and safety, as among the most important consumers' preference determinants, have constrained food industries to develop innovative production techniques. The industry is increasingly challenged with the task of developing high quality and nutritious products. Consumers are demanding for tastier, healthier and safer food products. Deep-fat frying is among the most important food processing operations especially in North America. It involves simultaneous transfer of heat and mass (moisture and fat) to a product at high temperatures leading to series of physical and chemical changes in the product (Bouchon, 2009). A typical fried product tends to have an attractive golden color along with peculiar texture and taste that are difficult to replicate with other processing methods. In order to satisfy consumer demands of food products that are perceived as being "more healthy", there is currently a major effort to develop novel techniques for reducing fat absorption during frying without sacrificing taste and flavor. Some of the new trends include development of new oils or selection of oils with improved stability during heating, development of oils with reduced trans fatty acids and designing new strategies for reducing oil absorption during frying (Li et al., 2002; Adedeji et al., 2009; Ngadi et al., 2009).

Frying is used to process potatoes into French fries. In the United States alone, production of French fries is a multi-billion-dollar industry. Development of an externally brown or golden color and a crispy crust is among the structural changes that occur during frying of potatoes (Pedreschi et al., 2001). Crust formation in fried potatoes is the

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Table 1 – The batter formulations used to coat potato strips.

Batter formulations	Batter ingredients
A	Modified starch (potato, corn, tapioca, wheat), leavening (sodium acid pyrophosphate, sodium bicarbonate)
B	Modified starch (potato), dextrin, leavening (sodium acid pyrophosphate, sodium bicarbonate)
C	Modified starch (tapioca, corn), color (paprika extract, turmeric extract)

result of changes in the original structure of the potato tissue when exposed to hot oil, i.e. at a temperature about 170–180 °C. Other changes include softening of the middle lamella between cells, starch gelatinization, and dehydration. Since potatoes have relatively high starch content, the major influence on texture would be due to gelatinization of starch during heating.

Starch gelatinization is the collapse of molecular arrangement in the starch granule resulting in granular swelling and loss of solubilization (Yusop et al., 2011). It plays an essential role in forming a crust region on the surface of fried foods and preventing oil uptake during frying. Crust permeability has been proposed as the main factor influencing the amount of fat uptake during frying (Gazmuri and Bouchon, 2009). In fact, most of the pre-frying treatments, such as pre-drying, pre- heating, and baking, have concentrated on surface structural changes and formation of crust with less permeability to oil absorption (Mellema, 2003; SuDer et al., 2009; Soorgi et al., 2012; Rahimi and Ngadi, 2014a,b). These pre-treatment techniques control starch gelatinization, glass transition temperature, and other microstructural changes on the surface of foods and consequently the amount of moisture evaporation and fat absorption through the crust during frying.

The glass transition temperature (T_g) of starchy food products such as fried potato strip is measured to understand the physicochemical and thermal behaviors of the starch-based products. The T_g of starch is a critical thermal property for starch- based products due to the multiple phase transitions that starch undergoes during heating and the instability (such as evaporation) of the water content of the products. In starch-based food products, T_g is an important parameter that determines textural changes (Versino et al., 2016), quality (Figueroa et al., 2016), stability (Zhao et al., 2015), product properties (van Koerten et al., 2015), and safety of food systems (Pan et al., 2016). van Koerten et al. (2015) investigated the crust morphology and crispness development during deep-fat frying of potato. The authors concluded that the crispness of the fries was not only enhanced by the porosity and crust thickness but the consequent increase in T_g of the product equally improved its crispness. Kawas and Moreira (2001) studied product quality attributes of tortilla chips during the frying process. The authors reported that raw tortilla and chips might experience physical and physicochemical deteriorations if the ambient temperature is above the T_g of tortilla chips. The glass transition is a physical change that is promoted by the addition of heat, water uptake and oil content of the product at different frying conditions. Glass transition can provide a useful information of the textural properties of the product.

Texture is a multi-parameter attribute, usually associated with physical, mechanical, geometrical and acoustic parameters. It is also related to structural re-arrangement and oil absorption in the product during frying (Llorca et al., 2001; Pedreschi et al., 2001; Rahimi and Ngadi, 2015, 2016a,b). Thus, interactions between perceived texture, physical and microstructure arrangements are complex. Crispness is an important descriptor of texture and a key driver of consumer preference. It is a measure of how brittle, crunchy, firm or soft a product is. It is typically correlated to the extent of freshness and eating pleasure of the product. In French fries, crispness is particularly important in determining textural quality. Frying creates a soft mealy interior and an external crispy outer crust in the French fry product. The interior is essentially cooked and slightly dehydrated cells, similar in texture to cooked potatoes. The exterior consists of largely dehydrated cells similar in texture to dried potatoes. The interaction between the crust and core regions determines the overall textural characteristics of the product. Thus, measurement and control of crispness are critical in defining the quality of French fries.

Crispness is traditionally evaluated using time-consuming sensory panels. Instrumental methods of texture measurements are often preferred since they are objective, consistent and relatively rapid. In broad terms, there are 2 approaches that can be used to measure crispness. These are namely a mechanical break related approach (Tran and Chen, 2013) and other approaches such as acoustic methods (Saeleaw and Schleining, 2011). Acoustic methods are based on complex analysis of fracture events. Crispness is inherently dependent on structural and microstructural changes in the product during frying. It is also dependent on the variety of the potato as well as pre-treatment applied and the frying process employed. Very limited information is available on the parameters that influence the development of crispness of potato fries during deep-fat frying and during holding time after removing French fries from a fryer.

The purpose of this study was to evaluate the effect of coating formulations and post frying holding time on French fry crispness development. The moisture and oil distribution in the core and crust regions was investigated. The study also examined changes in glass transition properties of fried potato strips held under heat lamp.

2. Materials and methods

2.1. Materials

Fresh potatoes (*Solanum tuberosum* L.) were purchased from a local supplier (Provigo, Montreal, QC, Canada), and stored at room temperature until use. Three different batter formulations containing different modified starches were used, namely: A, B, and C. The formulation of the batters is described in Table 1. Canola oil (Canola Harvest, Lethbridge, AB, Canada) was purchased from a local market in Montreal, Canada.

2.2. Batter preparation

An amount of 420 g dry batter was measured into a weigh boat, and 580 g of refrigerated water was added in a kitchen mixing bowl (Sumeet, CM/L-0973467, India) to prepare a 42 g/100 g batter mix. Refrigerated water delays leavening agent activity till frying process and prevents any change in the texture and microstructure before batters are fried. Using a whisk attachment, the batter mix was blended for 1 min, and then mixed for 9 extra minutes in a kitchen mixer on low speed (550 rpm). The batter mix was kept for 5 min at room temperature and finally used for potato strips coating.

2.3. Potato strips coating

The potatoes were washed, peeled and cut into 10 mm × 10 mm × 50 mm strips with a manual cutter. The potato strips were washed, soaked in distilled water to remove the excess starch, and finally transferred for batter coating. Potato strips of equal length (50 mm) were dipped in the prepared batter solutions to make a complete coating. Coated potato strips were then removed from the batter solution and kept in a wire basket for about 10 min to drain excess batter before transferring to the deep fryer. Non-coated potato strips were used as control samples. Therefore, 3 different coated potato strips were used for the experiments, namely: potato strips coated with batter-A, batter-B, and batter-C.