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Kinetics of oil uptake during frying of potato slices: Effect of pre-treatments

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Abstract

Oil uptake in fresh, blanched and, blanched and dried potato slices was studied during frying. Potato slices blanched in hot water (85 °C, 3.5 min) and potato slices blanched (85 °C, 3.5 min) and then dried until to a moisture content of ~60 g/100 g (wet basis) were deep fried in sunflower oil at 120, 150 and 180 °C. A control treatment consisted of unblanched potato slices without the pre-drying treatment (fresh samples). It was studied applying two empirical kinetic models in order to fit the oil uptake during frying: (i) a first order model; (ii) a proposed model, with a linear time behavior for short times, while time independent for long times. Oil uptake was high even for short frying times at the different temperatures tested suggesting that oil wetting is an important mechanism of oil uptake during frying. For control slices, oil uptake increased approximately by 32% as the frying temperature decreased from 180 to 120 °C at moisture contents $\leqslant$1 g water/g dry solid. No apparent effect of frying temperature in oil uptake was observed at moisture contents $\leqslant$0.5 g water/g dry solid in fried slices previously blanched and dried. The two kinetic models studied fitted properly the values of oil uptake during frying, with similar correlation coefficient r^2.

Keywords: Frying; Potato; Oil uptake; Kinetics

1. Introduction

Deep-fat frying is a widely used food process, which consists basically of immersion of food pieces in hot vegetable oil. The high temperature causes partial evaporation of the water, which moves away from the food and through the surrounding oil, and a certain amount of oil is absorbed by the food. Frying is often selected as a method for creating unique flavors and texture in processed foods that improve their overall palatability. The high temperature of the frying fat, typically leads to the appreciated textural characteristics of fried foods, and besides heating of reducing sugars effects a complex group of reactions, termed caramelization, leading to browning development (BeMiller & Whistler, 1996). This process involves simultaneous heat and mass transfer.

In 2001, about 57% of the potato US crop was processed producing 11,300 million kg of processed potatoes, of which 21.6% was made chips. The worldwide trade in 2001 shows that 7.4×10^7 kg of potato chips were exported with a value of 165 million dollars (Economic Research Service, 2004). Potato chips are very thin pieces (1.27–1.78 mm thick) of sliced raw potatoes that are fried to a final oil content of 33–38 g/100 g (wet basis) (Moreira, Castell–Perez, & Barrufet, 1999).

In potato chip production, potato slices are washed and dried on a flat wire conveyor to remove as much surface starch and water as possible (Gebhardt, 1996). Some potato processing plants use blanching prior to frying to improve the color of the chips. The blanching solution is heated to 65–95 °C and blanching takes

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~1 min. Consecutively, the excess of water is removed and potato slices are fried in a continuous fryer, where they remain from 1.5 to 3 min at 170 to 190 °C, until the moisture level is less than 2 g/100 g (wet basis). The frying time depends on the flow of slices to the fryer, the initial moisture level of the potato and the desired color. Subsequently, chips are conveyed, allowing excess oil to drain off, to be salted or flavored. Finally, potato chips are cooled on a conveyor and sorted by size before packaging.

Potato chips contain significant amount of fat, reaching in many cases ~1/3 of the total food product by weight (Mellema, 2003). This ensures a high level of satiety, but can also pose a risk. Especially, over the last decade the desirability of reducing fat content of deep fried products has been recognized. Therefore, consumer trends are moving toward healthier foods and low-fat products, creating the need to develop technologies to reduce the amount of oil in end fried products (Bouchon, Aguilera, & Pyle, 2003).

In order to obtain low-fat potato chips, it is useful to understand the mechanisms involved during the frying process, so that oil migration into the structure can be minimized. Numerous studies have shown that most of the oil is confined to the surface region of the fried potatoes (Pedreschi, Aguilera, & Arbildua, 1999; Bouchon & Aguilera, 2001; Bouchon, Hollins, Pearson, Pyle, & Tobin, 2001), and there is evidence that it is mostly absorbed after frying during the cooling period (Ufheil & Escher, 1996; Aguilera & Gloria-Hernández, 2000; Bouchon et al., 2003). Bouchon et al. (2003) explained that three different oil fractions can be identified as a consequence of the different absorption mechanisms in fried potato cylinders, that is: (i) structural oil (STO) which represents the oil absorbed during frying, (ii) penetrated surface oil (PSO) which represents the oil suctioned into the food during cooling after removal from the fryer, and (iii) surface oil (SO) which is the oil that remains on the surface. These authors showed that a small amount of oil penetrates during frying because most of the oil was picked up at the end of the process, suggesting that oil uptake and water removal are not synchronous phenomena.

In the potato chip process, raw potatoes are washed, peeled, sorted, and cut into slices. Some potato processing plants use blanching in hot water and drying with warm air until moisture content of 60 g/100 g (w.b.) is reached, prior to frying. After this, potato slices are usually fried in a continuous fryer with hot oil (170–0190 °C), where they remain until the moisture level is less than 2 g/100 g (w.b.). Finally, potato chips are salted, cooled in ambient air and packaged. The blanching step improves the color and texture, and could reduce the oil uptake by gelatinization of the surface starch (Califano & Calvelo, 1987). Air dehydration leads to a lower moisture content which also reduces oil absorption (Talburt, Weaver, Reeve, & Kueneman, 1987).

In recent years, several procedures have been proposed to reduce the amount of absorbed oil in fried potatoes. Rubnov and Saguy (1997) added fructose to a restructured potato product that resulted in a change of the surface properties, with a reduction of absorbed oil after frying. Soaking of potato strips in NaCl solutions could reduced oil uptake in ~15% in French fries after frying (Moyano, Rioseco, & González, 2002; Bunger, Moyano, & Rioseco, 2003). Pre-drying of potatoes is a common way to reduce fat uptake in the final fried product (Lamberg, Hallstrom, & Olsson, 1990; Moyano et al., 2002). Vacuum frying may be also an option for fried potatoes with low oil content and the desired texture and flavor characteristics (Garayo & Moreira, 2002). Since the properties of the surface of the potatoes are most important for fat uptake, the application of a proper coating is a promising route to reduce oil content (Mellema, 2003). There are many options available to reduce fat uptake by application of coatings or batters. For instance, Williams and Mittal (1999) used gellam gum to coat samples so that the resulting film reduced the oil uptake during frying.

Although several works have found that the majority of the oil uptake occurs in the post frying period (Sun & Moreira, 1994; Ufheil & Escher, 1996; Southern, Chen, Farid, Howard, & Eyres, 2000; Bouchon et al., 2003), different approaches has been used to describe the kinetics of oil uptake during frying . Gamble, Rice, and Selman (1987) correlated oil content of potato slices with frying time and with square root of frying time. Kozempel, Tomasula, and Craig (1991) tried a zero-order kinetic model for French fries. Chen and Moreira (1997) applied energy and mass balance equations, solving the set of differential equations by means of the finite difference techniques, to model the oil content in tortilla chips. Krokida, Oreopolou, Maroulis, and Marinos-Kouris (2001) used a first-order kinetics to describe the oil uptake in potato strips.

The principal objectives of this work were (i) to study the oil uptake during frying at three temperatures for: (a) control potato chips, (b) blanched potato chips, and (c) blanched and pre-dried potato chips and (ii) to apply two empirical kinetic models in order to fit the oil uptake data during frying.

2. Materials and methods

2.1. Materials

Potatoes (variety Panda, ~20 g/100 g (dry basis)) and sunflower oil (Chef^{TM}, Coprona, Chile) were the raw materials. Potatoes stored in a dark room at 8 °C and 95% of relative humidity were washed and peeled. Then,