

Oil distribution in potato slices during frying

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Abstract

The objective of this research was to study the kinetics of oil absorption and distribution in the structure of potato slices during frying, considering the effects of three oil temperatures and a blanching pre-treatment. Either raw or blanched potato slices (Desirée variety, diameter: 30 mm, thickness: 3.0 mm) were fried at three constant (± 1 °C) oil temperatures: 120, 150 and 180 °C. The blanching pre-treatment was accomplished in hot water at 85 °C for 3.5 min. Raw potato slices were used as the control for the experiments. The amount of oil absorbed was quantified during frying at four time intervals. The following fractions of the total oil (TO) content of potato slices were determined: (i) structural oil (STO); (ii) penetrated surface oil (PSO); and (iii) surface oil (SO). PSO constituted the highest fraction of the total oil content and this was the case for the control as well as the blanched slices, confirming that oil absorption in potato chips is mainly a surface phenomenon. Contrary to expectation, the blanched potato chips absorbed more oil than the control chips. The higher the frying temperature, the lower the oil absorbed by chips. Confocal laser scanning microscopy (CLSM) and scanning electron microscopy (SEM) allowed studying the surface topography of potato chips, and in some cases, the location of oil on the surface.

Keywords: Oil absorption; Potato slices; Oil distribution; Frying; Blanching

1. Introduction

Potato chips have been popular salty snacks for 150 years and its retail sales in US are about \$6 billion/year, representing 33% of the total sales of this market (Garayo and Moreira, 2002; Clark, 2003). Frying in hot oil is characterized by very high water removal rates, which critically influence the mechanical as well as structural properties of the chips (Baumann and Escher, 1995; Hindra and Baik, 2006). The moisture content of chips decreases from around 80% to almost 2% when they are fried. However, the moisture removal inevitably leads to a considerable uptake of oil which amounts to around 35% of the mass of the chip (Aguilera and Gloria-Hernández, 2000).

Numerous studies have shown that most of the oil is confined to the surface region of the fried potatoes (Pedreschi et al., 1999; Bouchon et al., 2003; Bouchon et al., 2001), and there is evidence pointing to the fact that the oil mostly penetrates into the structure after it is removed from oil and during the cooling period (Ufheil and Escher, 1996; Aguilera and Gloria-Hernández, 2000; Bouchon et al., 2003; Durán et al., 2007). In order to obtain low-fat potato chips, it is necessary to understand the mechanisms involved during the frying process, so that oil migration into the structure can be minimized.

Durán et al. (2007) implemented a methodology to determine the oil fractions in potato chips accurately, easily and rapidly. During the initial period of frying (~40 s and later), the total oil content of the product increases considerably, and then it remains almost constant throughout the duration of frying and even during the cooling stage when

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the chips have a moisture content of ~ 2 g water/g dry solids. Nevertheless, once the product is removed from the fryer, oil partition between the surface and the bulk gets inverted and only $\sim 35\%$ remains on the surface whereas $\sim 65\%$ penetrates into the chip microstructure due to vacuum forces created by evaporative cooling. These results are in agreement with those found by Ufheil and Escher (1996), who also reported that most of the oil was absorbed when the potato slices were removed from the fryer. Finally, Moreira et al. (1997) found in the case of tortilla chips that only 20% of the final oil content was absorbed during frying and that almost 64% of the total oil content was absorbed during cooling, leaving only 36% the total oil at the tortilla surface. After cooling, the oil was located either on the surface of the tortilla chips or sucked into the porous crust microstructure.

Since most of the oil is taken up after removal from the oil, the conditions under which the potato pieces are removed from the fryer are important for fat absorption (Bouchon et al., 2003; Aguilera and Gloria-Hernández, 2000; Ufheil and Escher, 1996; Durán et al., 2007). Surface structure plays an important role in the phenomenon and the greatest part of oil is retained in form of drops in the crust of the fried piece after it is cooled. Bouchon et al. (2003) defined three different oil fractions which can be identified as a consequence of the different absorption mechanisms in fried potato cylinders, such as: (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 and does not penetrate into microstructure. These authors showed that a small amount of oil penetrates in potato cylinders 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.

The objective of this research was to study the kinetics of oil uptake and its partition in the microstructure of raw and blanched potato slices during frying at three oil temperatures (120, 150 and 180 °C).

2. Materials and methods

2.1. Materials

Potatoes (variety Desirée) and vegetable oil (Chef, Coprona, Chile) were the raw materials. Potato tubers were stored at 8 °C and 95% relative humidity. Slices (thickness of 3 mm) were cut from the pith of the parenchymatous region of potato tubers using an electric slicing machine (Berkel, model EAS65, UK). A circular cutting mold was used to provide chips with a diameter of 37 mm. Table 1 shows the chemical composition of the potato variety used in this research.

The reducing sugar content of the potato tubers used remained more or less constant during storage.

Table 1
Chemical composition of potatoes from Desirée variety

Component	g/100 g (wet basis) ^a
Water	77.23 ± 0.46
Protein	2.73 ± 0.0.36
Fat	0.30 ± 0.05
Ash	0.97 ± 0.18
Carbohydrates	18.77 ± 0.30
Reducing sugars	1.10 ± 0.01

^a Mean value ± standard deviation.

2.2. Blanching

Slices were rinsed for 1 min in distilled water, immediately after cutting, to eliminate some starch adhering to the surface prior to frying. Blanched samples were prepared by heating raw slices in hot water at 85 °C for 3.5 min [potato-to-water ratio (0.25 w/w)]. Raw slices were considered as the control. All slices were kept between humidified paper towels to avoid excessive dehydration before frying.

2.3. Oil dyed with Sudan red preparation

A heat resistant dyed oil (which has the same penetration behavior in frying products as the frying oil) was prepared by dissolving 1 g of the fat soluble and heat resistant stain Sudan Red B (Sigma chemicals) in 1 L of the frying oil (Bouchon et al., 2003). The oil mixed with the stain was heated and stirred over a hot plate at 60 °C for 4 h until the stain dissolved completely. Then, the dyed oil was left to cool to ambient temperature.

2.4. Frying experiments

In the present study we followed the methodology implemented by Bouchon et al. (2003) in order to distinguish and quantify the following three oil fractions in potato chips: (i) structural oil (STO): which is the oil that penetrates into the potato microstructure during frying; (ii) penetrated surface oil (PSO): which is the surface oil suctioned during cooling after the product is removed from the frying oil; (iii) surface oil (SO): which is the oil adhering to the surface during cooling. The addition of SO plus PSO and SO gives the total oil content (TO).

At each frying temperature, slices were fried for four different time intervals until they reached a final moisture content of (1.8 g/100 g wet solid). The frying times required to achieve this moisture content under various experimental conditions were previously determined. Ten slices per sampling time were deep-fried in hot oil contained in an 3 L capacity electrical fryer (Rival, Model CZF575, China) at each of the three temperatures (120, 150, and 180 °C) for blanched and unblanched slices. The frying temperature was kept nearly constant (± 1 °C) by a controller system Watlow (model SD, USA). Temperature gradients in the

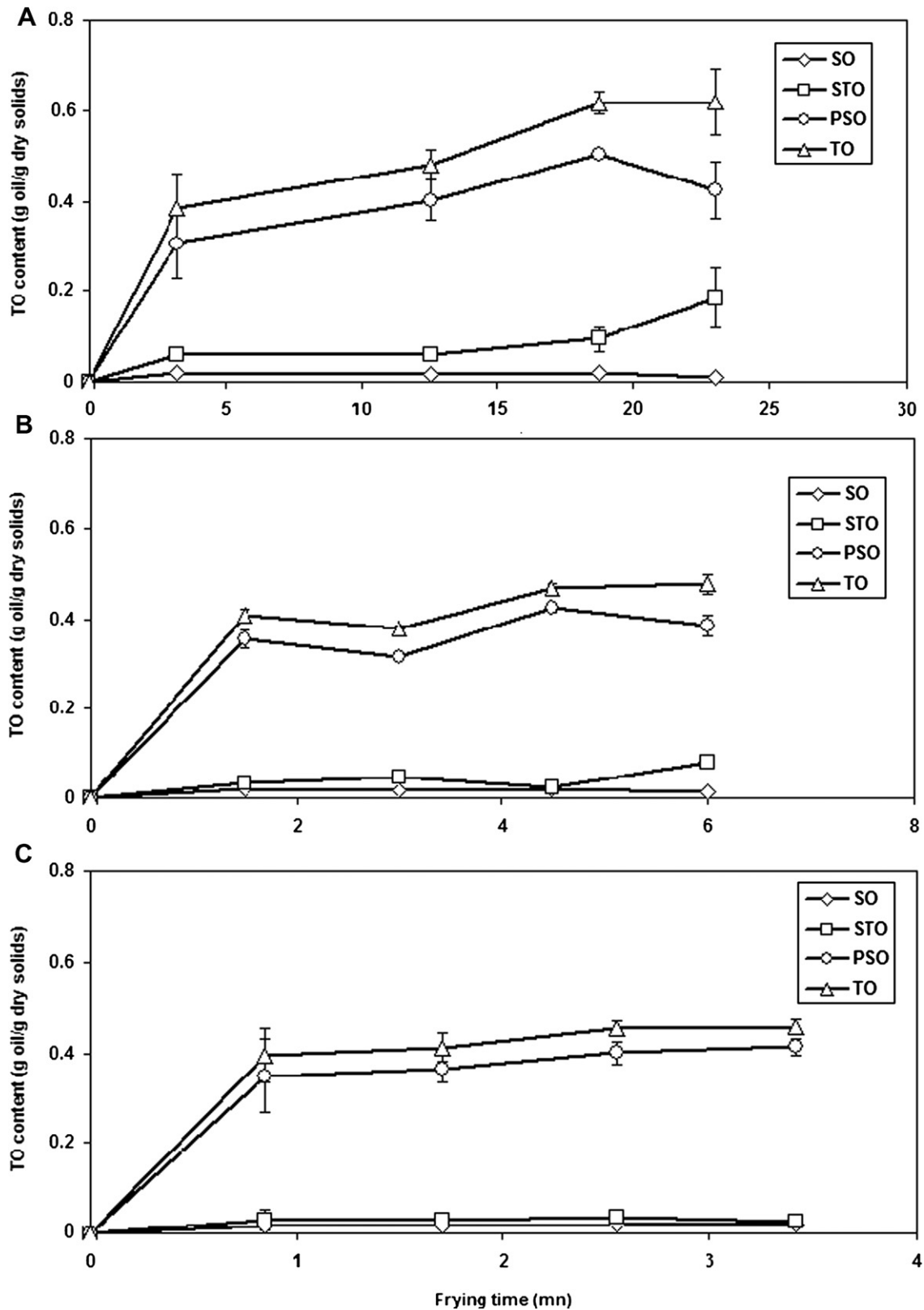


Fig. 1. Kinetics of oil uptake fractions and total oil in control potato slices during frying at: (A) 120 °C; (B) 150 °C; (C) 180 °C. TO: total oil; PSO: penetrated surface oil; SO: surface oil; STO: structural oil.

oil were minimized by using a multi-speed stirrer (Powerstat, model 3PN216B, USA) set at a rotational speed of 30 rpm, placed in the center of the fryer. The fryer was

filled with 2.5 L of oil which was previously heated to the desired frying temperature (120, 150, and 180 °C). The 10 slices were held in horizontal position using a wire structure

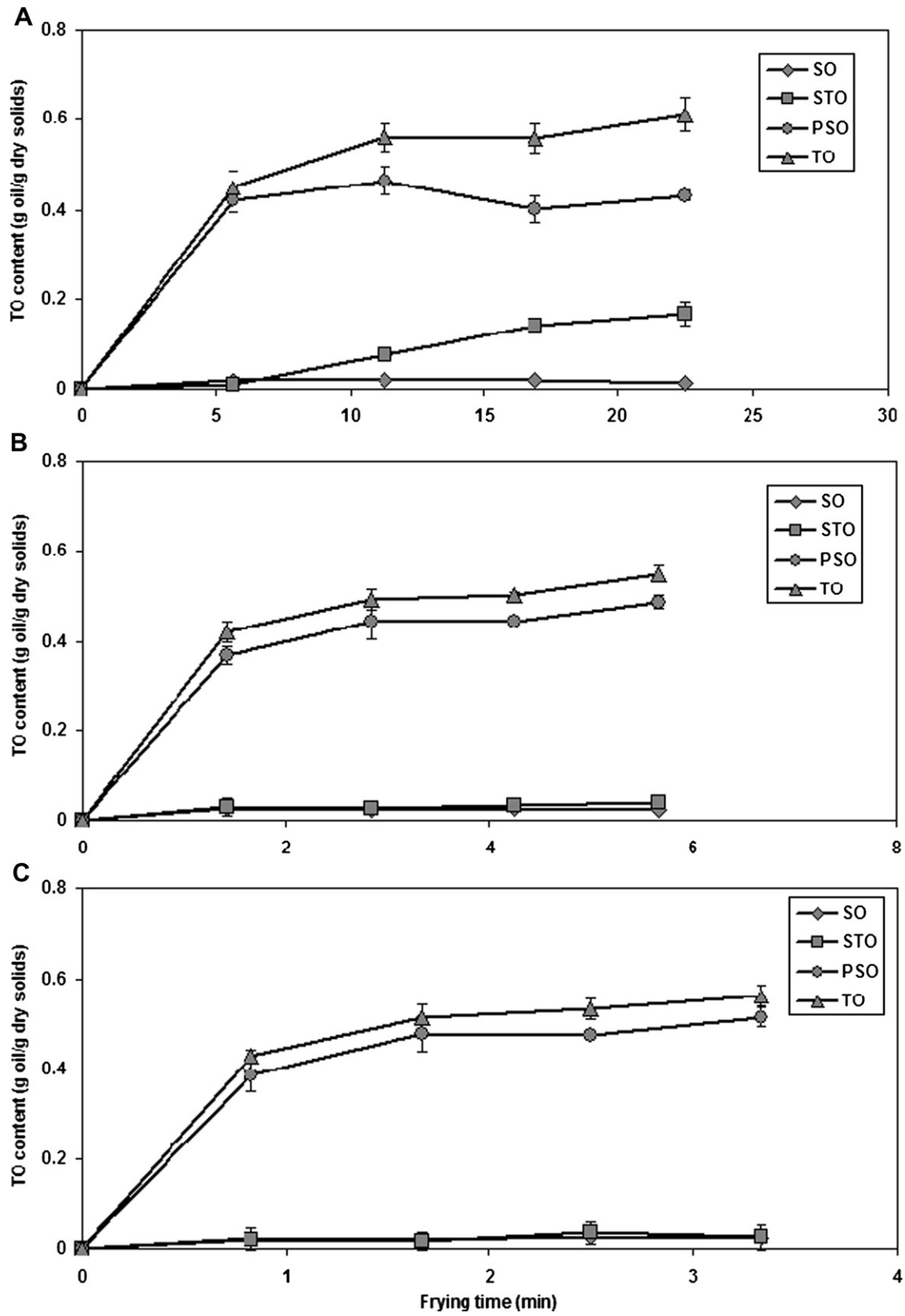


Fig. 2. Kinetics of oil uptake fractions and total oil in blanched potato slices during frying at: (A) 120 °C; (B) 150 °C; (C) 180 °C. TO: total oil; PSO: penetrated surface oil; SO: surface oil; STO: structural oil.

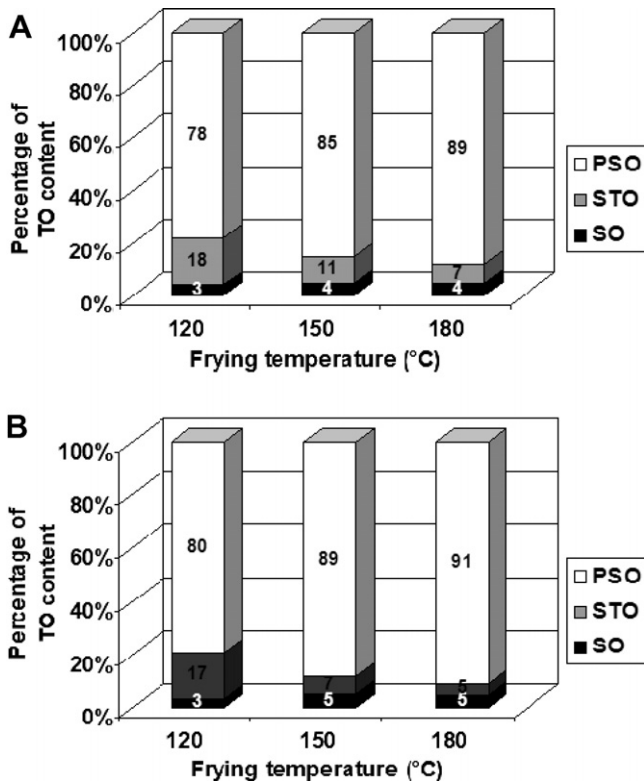


Fig. 3. Average oil fractions absorbed by control (A) and blanched (B) potato slices during frying at 120, 150 and 180 °C. TO: total oil; PSO: penetrated surface oil; SO: surface oil; STO: structural oil.

to prevent them from floating in the oil. Twenty seconds before ending each running, 0.17 L of dyed indicator oil solution was added over the next 10 s. This solution was previously heated on a temperature controlled heating stirring plate (Velp, model AREX, Italy). The turbulence generated by the stirrer ensured instantaneous mixing of the two oils. The 10 slices were removed from the fryer and left to cool at room temperature for 10 min in order that excess

oil could be drained off. The potato slices were weighed in order to record their final mass using an analytical balance (OHAUS, model GA110, USA).

Oil temperature during frying was measured using a thermocouple (Type E) connected to a data acquisition system, comprising a data-logger (Omega, OM-300, New Zealand) and a personal computer. The temperature was recorded at 1 s intervals. Experiments were run in duplicate for all the pre-treatment and oil temperatures tested.

2.5. Chemical analysis

2.5.1. Moisture content

Moisture content of the samples were analyzed according to the procedure described in the AOAC (1995) by drying the samples in a vacuum oven (Shel Lab, model 1410-E, USA) for 12 h until they reached constant weight.

2.5.2. Reducing sugar content

The analysis was done only for raw potatoes using the Munson & Walker methodology described by AOAC (1995).

2.5.3. Proximate analysis

This analysis was done in raw potatoes using the procedure described in AOAC (1995) to determine their chemical composition showed in Table 1.

2.5.4. Calibration curve to determine Sudan Red concentration in the frying oil

Solutions of different concentrations of Sudan Red were prepared. Each solution was diluted nine times by volume with petroleum ether (JT Baker, USA) and the absorbance was measured at 509.6 (maximum absorbance) by means of a spectrophotometer (Hach, model DR/3000, USA). A linear plot was obtained between the concentration of the dyed oil and absorbance over the whole concentration range of interest.

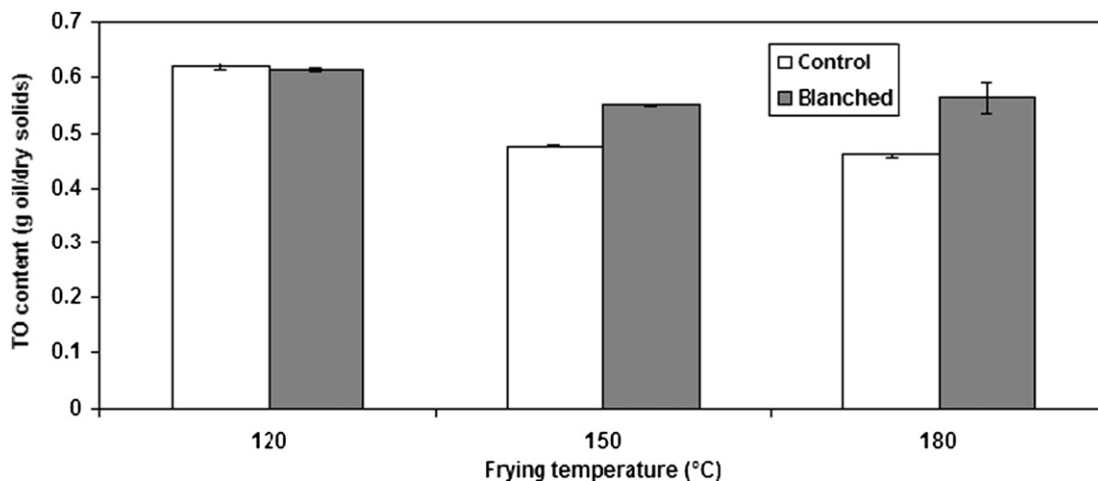


Fig. 4. Total oil (TO) content in the final potato slices (moisture content ~1.8%, total basis) fried at 120, 150 and 180 °C.

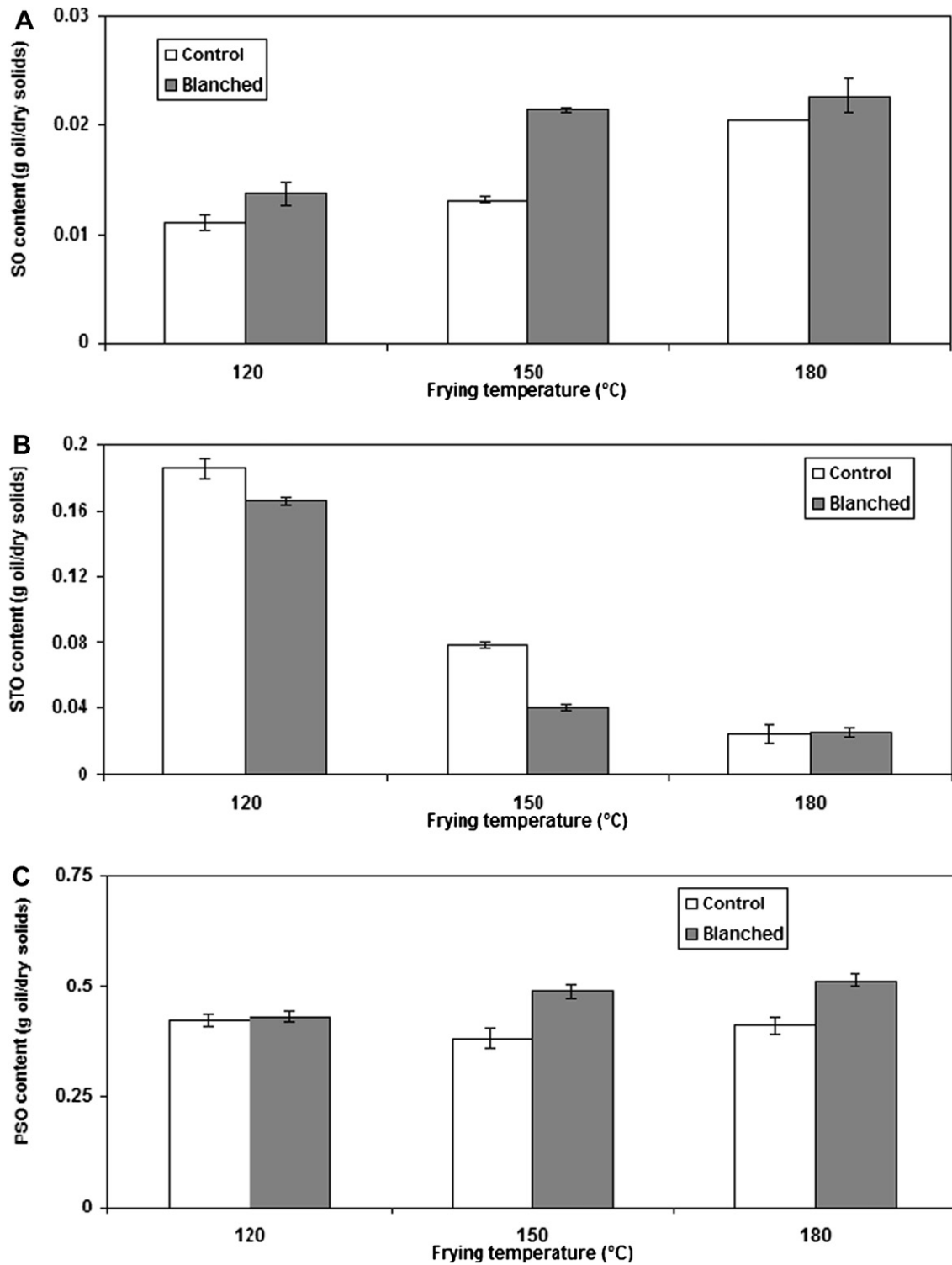


Fig. 5. Content of the following oil fractions in the final product (moisture content \sim 1.8%, total basis) fried at 120, 150 and 180 °C: (A) SO: surface oil; (B) STO: structural oil; (C) PSO: penetrated surface oil.

2.5.5. Determination of oil fractions

Oil fractions in potato chips were extracted and quantified according to the methodology implemented by Bouchon et al. (2003) for fried potato cylinders:

2.5.6. (i) Surface oil (SO)

SO was removed from the 10 slices collected at each frying time by immersing them in 150 mL of petroleum ether for 1 s at ambient temperature. The extracted oil was

collected by evaporating the solvent under vacuum using a rotary evaporator (Fisatom, model 803, Brazil). The flasks containing the extracted oil were dried to constant mass in a vacuum oven (Shel Lab, model 1410-E, USA).

2.5.7. (ii) Penetrated surface oil (PSO) and structural oil (STO)

The oil remaining after the removal of SO from the slices was determined by finely cutting the slices and drying in a vacuum oven (Shel Lab, model 1410-E, USA) at 50 °C for 12 h. The dried solids were then ground, weighed and transferred into single cellulose extraction thimbles (Watman, UK) which were placed in dry 250 mL round bottom flasks containing 50 mL of petroleum ether. Oil extraction was carried out for 2 h using a soxhlet system (Tecator, model HT&, Sweden) and the solvent was evaporated using a rotary evaporator (Fisatom, model 803, Brazil), according to AOAC (1995). The flasks containing the extracted oil were dried to constant mass in a convective oven at 105 °C. For analysis, soxhlet extracted oil was diluted nine times by volume with petroleum ether and the absorbance was measured at 509.6 nm. The amount of dyed (PSO) oil was calculated using Eq. (1) below. This fraction corresponds to the oil that was picked up at the end of the frying process that had penetrated into the structure of the product after cooling (PSO).

$$\text{PSO (g)} = \frac{\text{Soxhlet extracted oil (g)} \cdot \text{dye concentration in extracted oil (g/L)}}{\text{dye concentration in oil bath (g/L)}} \quad (1)$$

The amount of non-dyed oil (STO) was calculated as follows:

$$\text{STO (g)} = \text{Soxhlet extracted oil (g)} - \text{PSO (g)} \quad (2)$$

2.5.8. Solid content

Each extracted sample was placed in a metal dish and dried in an air oven which was maintained at 105 °C and kept for 24 h until constant mass was obtained.

2.6. Microscopic analysis

Confocal laser scanning microscopy (CLSM) and scanning electron microscopy (SEM) were used to observe the oil distribution and the surface morphology of the fried samples. A CLSM microscope (Carl Zeiss, Oberkochen, Germany, model Axiovert 135M) was used in its fluorescence mode to observe the oil location in potato chips, or in its reflective mode to observe the topography of fried potato slices as described by Pedreschi and Aguilera (2002).

For studying location of the oil in the chips, the slices were fried simulating the above conditions inside hot oil mixed with the fluorochrome Nile Red (NR, N-3013) from Sigma Chemical Co., (Color index: 3013, St. Louis, MO) at a NR concentration of 0.0192 mg/mL according to Pedreschi et al. (1999). Fried slices were observed by fluorescence

CLSM directly or before being washed for 1 s in petroleum ether after a cooling period of 10 min under illumination with the Ar laser ($\lambda = 488$ nm). Image rendering for 3D reconstruction of the serial images obtained by CLSM Carl Zeiss was performed using Carl Zeiss LSM software (version 3.92).

Scanning electron microscopy (SEM) allowed observing the surface of potato chips. A gold coat (20 nm) was applied over the fried potato surface sample using a sputter coater (Sputtering System Hummer 6.2). Samples were examined at 10 keV using a Jeol JSM-S410 scanning electron microscopy (Tokyo, Japan).

For surface topography observations, the potato slices were fried in non-dyed oil (i.e. without NR) simulating the above conditions and the samples were observed either by CLSM in its reflective mode or by SEM.

2.7. Statistical analysis

Analysis of variance was carried out using statistical package (Statistical Graphics Corporation, Version 4, Rockville, USA) including multiple range tests ($P < 0.05$) for separation of least square means.

3. Results and discussion

Fig. 1 shows kinetics of total oil (TO) uptake and their different fractions (PSO, STO, and SO) in the structure of control potato chips fried at 120, 150 and 180 °C. At very

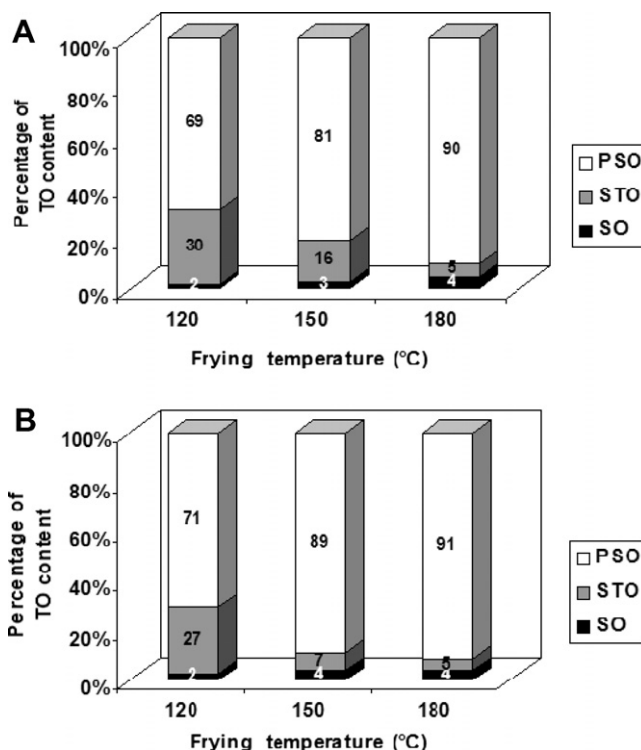


Fig. 6. Oil distribution in the final product (moisture content ~1.8%, total basis) fried at 120, 150 and 180 °C. (A) Control; (B) blanched. TO: total oil; PSO: penetrated surface oil; SO: surface oil; STO: structural oil.

short frying times (between 1 and 4 min) almost 75% of the total oil content of final control potato chips (chips with $\sim 1.8\%$ of moisture content in total basis) is absorbed. After that time interval, the TO content remained almost constant until the moisture content (total basis) reached 1.8% . As the frying temperature decreased, the frying time required to reach that final moisture content and the TO increased. Similar results have been found in pre-treated potato chips, fried potato cylinders and tortilla chips (Durán et al., 2007; Bouchon et al., 2003; Moreira et al., 1997). This result suggests that the total oil in potato chips is absorbed almost in the initial stage of frying once the potato slices are placed inside the hot oil. A similar trend was found in the case of blanched potato chips as shown in Fig. 2. Almost 75% of the total oil content of the fried product (chips with $\sim 1.8\%$ moisture content) was attained soon after immersion in the frying oil (between 1 and 6 min).

The distribution of oil fractions during frying followed the same trend in both control and blanched slices (Fig. 3). PSO constituted the highest fraction of TO during frying of the control as well as the blanched slices. The higher the frying temperature, the higher the percentage of PSO based on the TO content (e.g. 78%, 85% and 89% for 120, 150 and 180 °C respectively, and, 80%, 89% and 91% for 120, 150 and 180 °C, respectively). When the slices were removed from the fryer, a higher temperature difference develops between the surface and the interior, which, in turn, generates a higher negative pressure in the pore space leading to more oil penetration into their microstructure during cooling. This fact confirms that the oil absorption is principally a surface phenomenon (Ufheil and Escher, 1996; Aguilera and Gloria-Hernández, 2000; Bouchon et al., 2003; Durán et al., 2007). STO is the second important fraction in the TO content during frying of both control and blanched slices (Fig. 3). As the frying

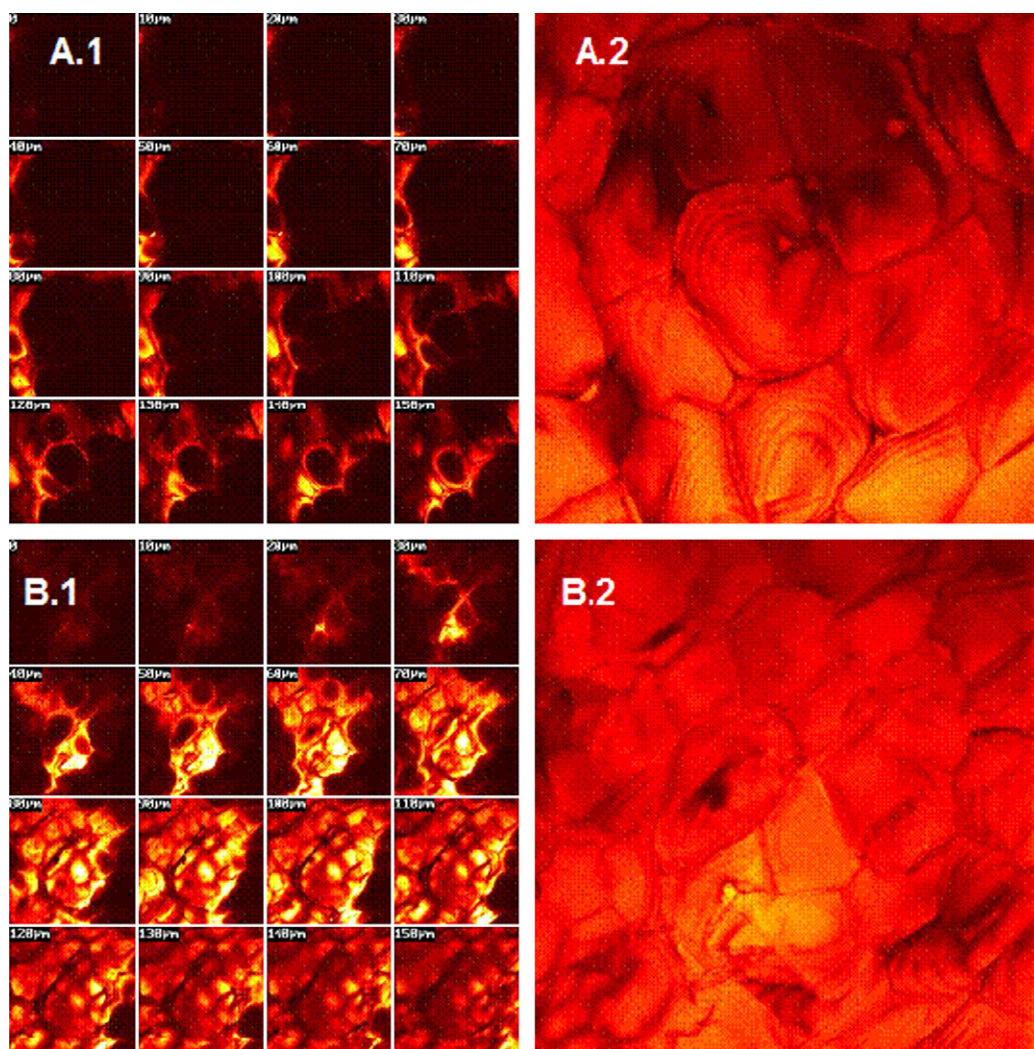


Fig. 7. Fluorescence mode CLSM images of oil distribution in control (A) and blanched (B) potato chips (moisture content $\sim 1.8\%$, total basis) fried at 150 °C. (1) Gallery of CLSM images at different depths; (2) 3D reconstructions of CLSM galleries shown in (1). Each image in the gallery and the 3D image: 640 × 640 μm .

temperature increases, STO penetration drops, since the higher internal pressures developed at higher temperatures makes it more difficult for the frying oil to penetrate the potato structure whilst inside the fryer. The percentage of STO ranged between 7–18% and 5–17% for control and blanched slices, respectively. This confirms that a small amount of oil penetrates during frying, because most of the oil is picked up at the end of the process, suggesting that oil uptake and water removal are not synchronous phenomena. The SO fraction was the lowest constituent of TO content (approximately 4% of the total oil content) and remained almost independent of the frying temperature.

TO content in the final product (moisture content of 1.8% total basis) depended not only on the frying temperature but also on the pre-treatment (i.e. blanching) (Fig. 4). Blanching increased oil absorption considerably when frying was undertaken at 150 and 180 °C. As the frying temperature decreased, the oil absorption increased significantly

($P < 0.05$). Microstructural changes in the potato tissue makes the blanched potato slices absorb more oil than control potato slices after frying (58% vs. 51% as an average for blanched and control potato chips). This phenomenon has been observed by Moyano and Pedreschi (2006) for blanching treatment undertaken at the same temperature–time combination.

SO, STO and PSO content of final control and blanched potato chips are shown in Fig. 5. SO content increased significantly ($P < 0.05$) with frying temperature for blanched chips. Contrary to this trend, the STO content dropped as the frying temperature increased. Blanched chips fried at 150 °C showed considerably lower STO content than the control chips. Finally, the PSO content increased with oil temperature and blanching treatment. As shown in Fig. 6, PSO content was the highest oil fraction not only in the control but also in blanched chips, followed by the STO fraction and the SO fraction. These results are similar to those shown in Fig. 3 for average values of the

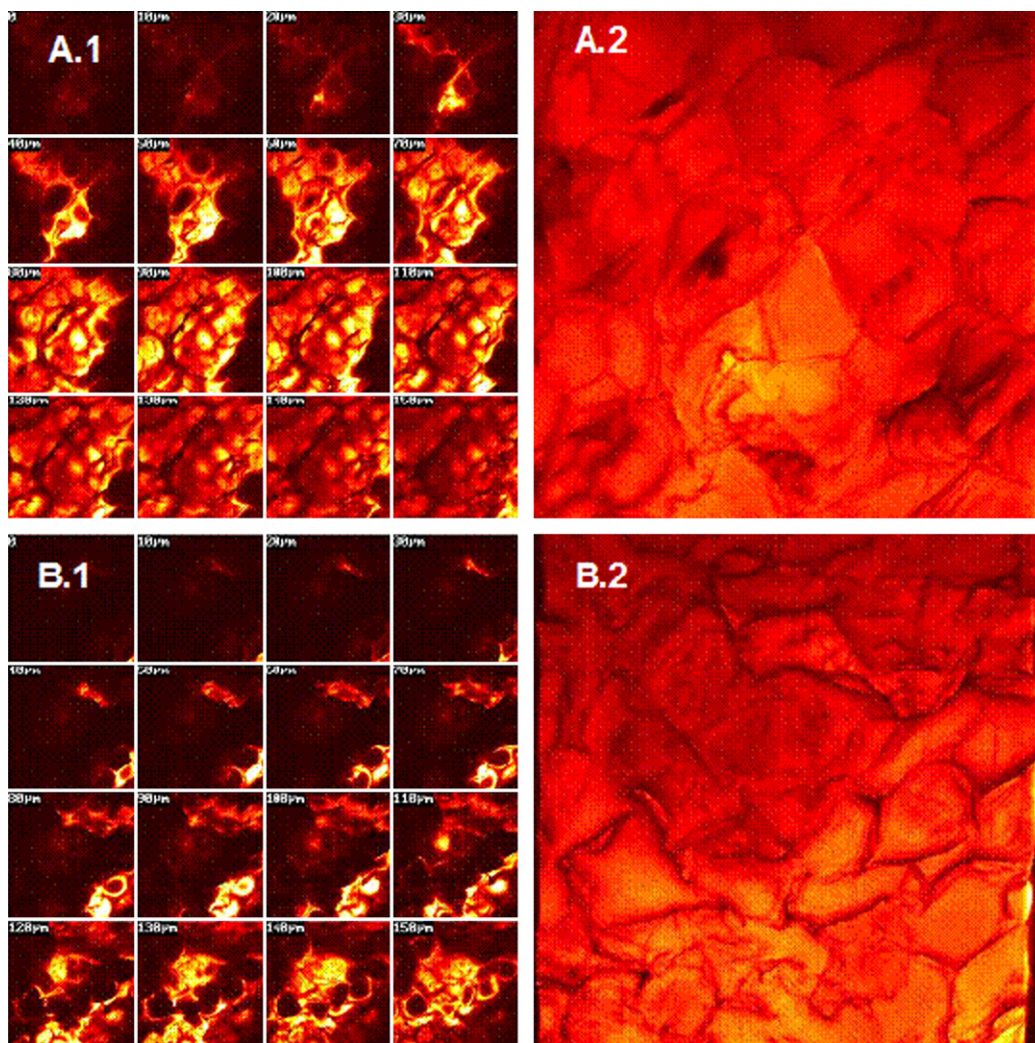


Fig. 8. Fluorescence mode CLSM images of oil distribution in blanched (A) and blanched and petroleum ether washed for 1 s after frying (B) potato chips (moisture content ~1.8%, total basis) fried at 150 °C. (1) Gallery of CLSM images at different depths; (2) 3D reconstructions of CLSM galleries shown in (1). Each image in the gallery and the 3D image: 640 × 640 µm.

percentages of oil fraction during frying of control and blanched potato slices at 120, 150 and 180 °C.

Oil location and surface morphology are important targets in microstructural studies of the fried potato tissue. CLSM was used to observe some important microstructural aspects of the frying such as the oil location and surface morphology. Figs. 7 and 8 show potato chips fried in oil containing the thermoresistant fluorescent probe Nile Red which were directly observed by CLSM, thus avoiding artifacts associated with sample preparation for light microscopy. This, together with the fact that CLSM makes optical sections in the samples at different depths (rather than physical sectioning for classical microscopy) allowed observation of oil distribution in the crust as close to the real situation as possible (Pedreschi et al., 1999). Fig. 7A and B show different patterns of oil distribution in control and blanched samples, respectively. Fig. 7A shows that oil in the surface layers of control potato chips is located preferentially around the cells in their walls. Pedreschi et al. (1999) using CLSM demonstrated that oil location in the crust of potato chips was like an “egg-box” surrounding intact dehydrated potato cells but did not penetrate into them, which was later confirmed by Bouchon and Aguilera (2001). On the other hand, in blanched potato chips fried at 150 °C, oil in the surface layers is mostly covering concave

irregular surfaces corresponding probably to cells whose walls were disrupted during cutting of the raw slices, before frying and blanching (Fig. 7B). Three-dimensional reconstructions of the CLSM image galleries of Fig. 7A and B are shown in Fig. 7A1 and A2, respectively. Fig. 7A1 shows that oil location follows the cell shapes locating preferentially inside the intercellular spaces or in the cell walls. Fig. 7A2 shows that surface oil in blanched chips is mostly accumulated over the entire surface scanned, covering uniformly the cells and the intercellular spaces.

Fig. 8 shows the effect that washing with petroleum ether (to remove SO) has on the blanched potato chips. Fig. 7B shows that most of the oil shown in Fig. 7A is removed after washing with petroleum ether leaving some concave cells free of oil. This fact can be confirmed by the 3D reconstructions shown in Fig. 7A2 and B2 for blanched, and blanched and washed potato chips fried at 150 °C. Principally, the oil covering the cells was easily removed by petroleum ether, while that remaining in the intercellular spaces did not get extracted and remained trapped within the microstructure.

The surface of fried potatoes is supposed to play a key role in frying, but its observation without artifacts has been elusive to food engineers. Reflective mode of CLSM allowed the observation of changes in the surface during

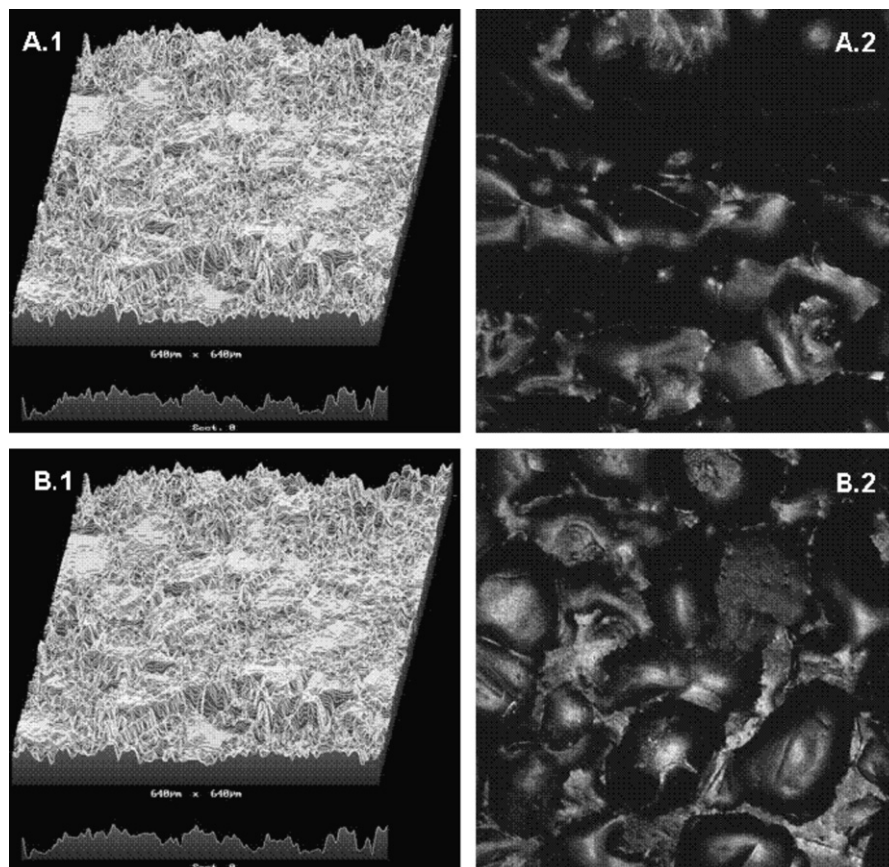


Fig. 9. CLSM reconstruction of the topographical surface of control (A) and blanched (B) potato chips (moisture content ~1.8%, total basis) fried at 150 °C. (1) 3D topographical representation of the surface; (2) 3D image of the reconstructed surface. Area of the 3D image: 640 × 640 µm.

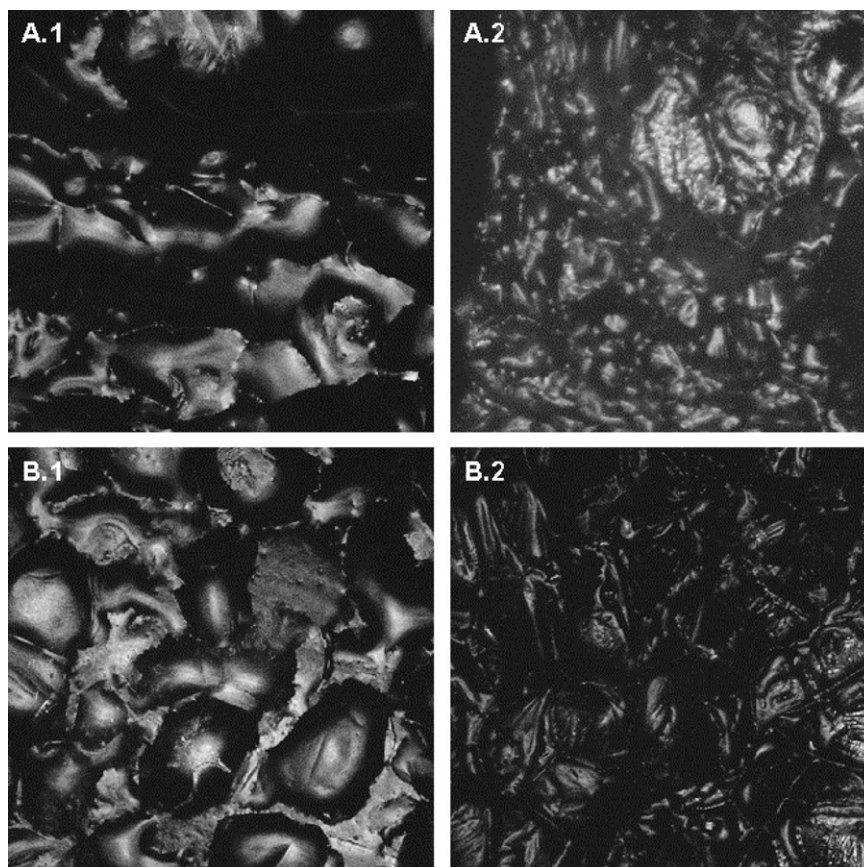


Fig. 10. CLSM 3D images of the surface of the control (A) and blanched (B) potato chips (moisture content $\sim 1.8\%$, total basis) fried at $150\text{ }^{\circ}\text{C}$. (1) without washing in petroleum ether; (B) washed in petroleum ether for one second after frying. Area of the 3D image: $640 \times 640\text{ }\mu\text{m}$.

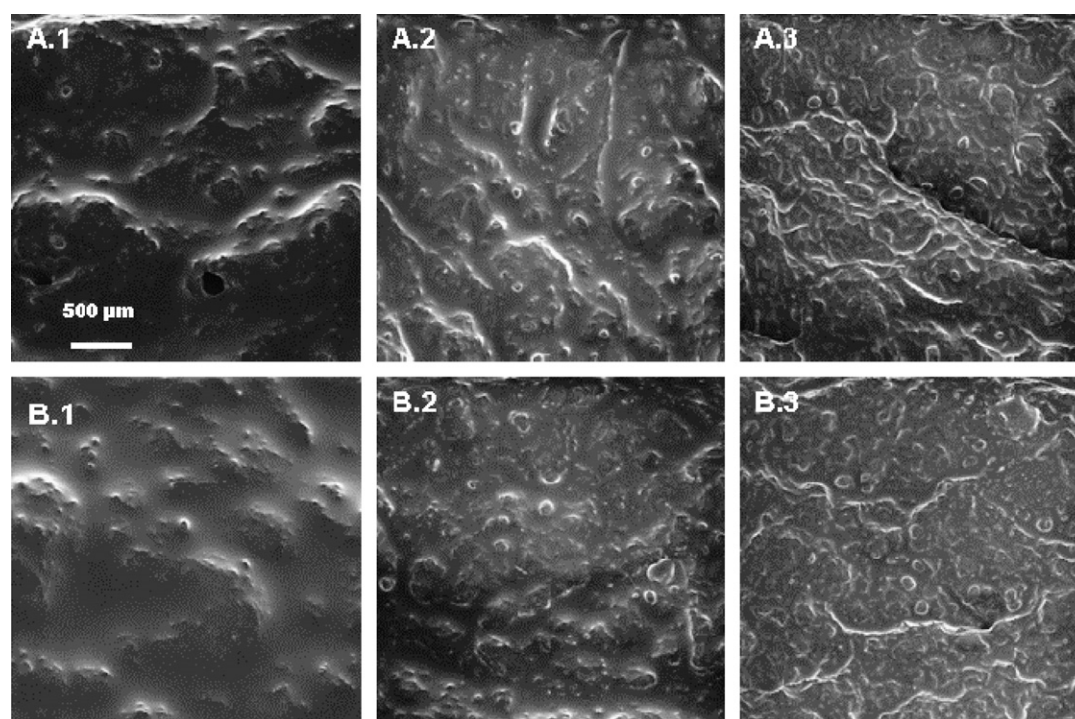


Fig. 11. SEM images of the surface of control (A) and blanched (B) potato chips (moisture content $\sim 1.8\%$, total basis) fried at: (1) $120\text{ }^{\circ}\text{C}$; (2) $150\text{ }^{\circ}\text{C}$; (3) $180\text{ }^{\circ}\text{C}$.

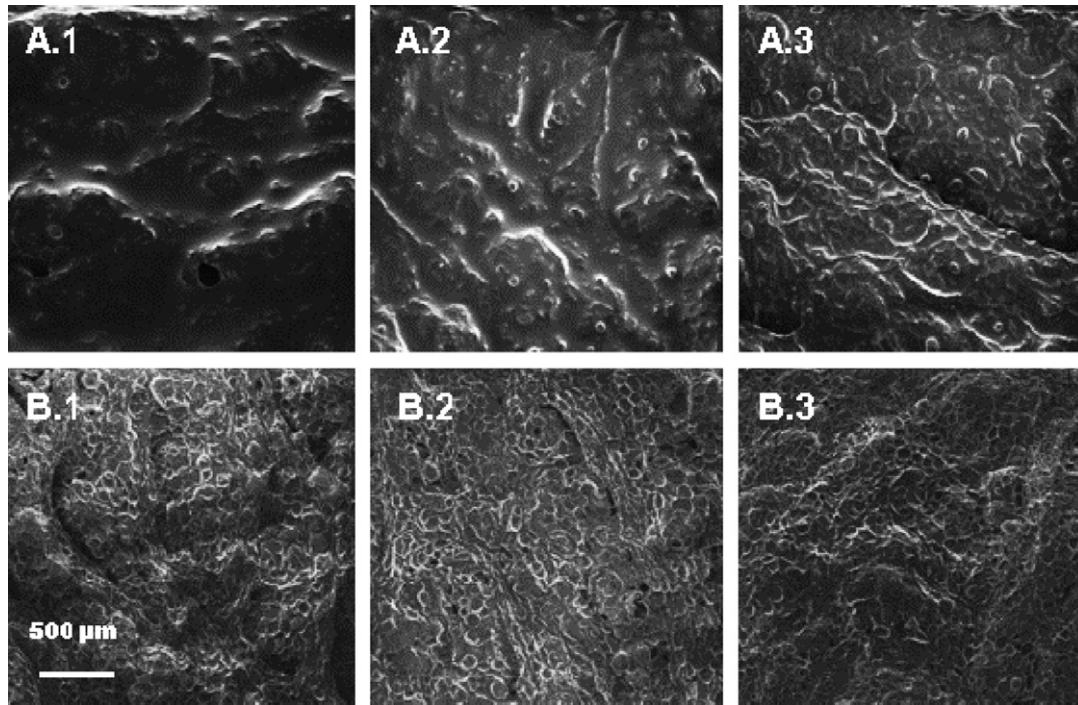


Fig. 12. SEM images of the surface of control (A) and petroleum ether washed control for 1 s after frying (B) potato chips (moisture content \sim 1.8%, total basis) fried at: (1) 120 °C; (2) 150 °C; (3) 180 °C.

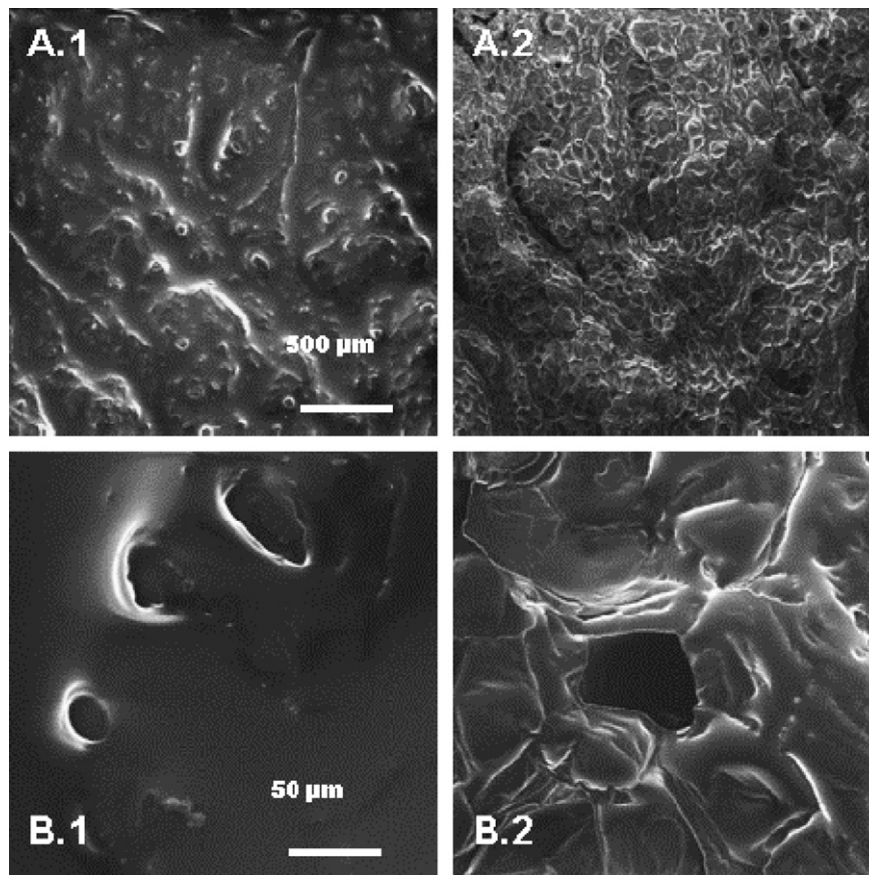


Fig. 13. SEM images of the surface of control (1) and petroleum ether washed control for 1 s after frying (2) potato chips (moisture content \sim 1.8%, total basis) fried at 150 °C and observed at two magnifications: (1) 35 \times ; (2) 350 \times .

frying with minimal intrusion. Fig. 9 shows the surface topographical reconstruction of control and blanched potato chips, respectively (Fig. 9A1 and B1, respectively). On the other hand, Fig. 7A2 and B2 depict the reconstructed surface of a control and blanched chip, respectively, as a pixel intensity map where some open concave potato cells and regions with higher brightness level representing zones of oil accumulation. Blanching prior to frying can gelatinize some surface starch making the resulting surface different from that of the control samples, in the process, leading to the blanched chips absorbing more oil than control chips. The final oil uptake will be strictly linked to potato microstructure and to time-temperature combination used for the blanching treatment (Álvarez et al., 2000). Pedreschi et al. (2000) using scale-sensitive fractal analysis quantified important changes in parameters describing surface roughness of potatoes during frying such as the area-scale fractal complexity (Asfc) and the smooth-rough crossover (SRC).

Since oil absorption seems to be fundamentally a surface related phenomena it is very important to observe the surface topography of potato chips and follow changes occurring during frying. Fig. 10A shows 3D reconstructions of the control and blanched (without and with petroleum ether) potato chips using serial images obtained by CLSM in its reflective mode. Details of the cell structure such as size heterogeneity can be observed with high resolution. Surface cells are bounded by cut cell walls leaving available space for oil deposition after frying. When the control and blanched chips were washed with petroleum ether, the resulting 3D images (Fig. 10A2 and B2) showed much less brightness indicating a considerable elimination of the oil from the surface of potato chips after frying.

SEM was another powerful tool used to study the surface topography of potato chips. Fig. 11 indicates that the surface topography changed as the frying temperature increased. The images of the blanched potato chips look smoother than those of control chips, since blanched chips tend to accumulate more oil that covers the surface. Fig. 12 shows that control potato chips lost a considerable quantity of surface oil after they were washed in petroleum ether, which allows clear observation of the cellular microstructure of the surface (Fig. 12B1, B2 and B3). This fact is confirmed by Fig. 13 at different scales of observation where the samples washed in petroleum ether showed clearer topographical details of the surface, mainly at a magnification of 350 \times .

4. Conclusions

Blanching increases the TO content of potato chips as well as decreases the frying temperature to attain a given moisture content in the product. The TO content was formed mostly by PSO, secondly by STO and finally by

SO. Almost all of the TO content was absorbed by the potato chips in the first few minutes of frying. Oil absorption in potato chips is mainly a surface phenomenon which mostly takes place when the chips are removed from the fryer (during the cooling process). CLSM and SEM allow studying the surface topography of potato chips, and in some cases, the oil location on the surface.

Acknowledgements

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