NaCl soaking treatment for improving the quality of french-fried potatoes

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Abstract

Potato strips were soaked in 3, 5 or 7% NaCl solutions (25 °C) previous to frying, to study the effect on oil uptake. Sensory responses indicated the best texture and lowest oil uptake at 3% NaCl solution for 50 min. Soaking had no effect ($P < 0.05$) on color (L^*, a^* and b^*) or moisture loss during deep fat frying at 180 °C. Soaking significantly reduced oil uptake from 0.13 to 0.10 g oil/g dry matter and increased the measured texture parameters (hardness to penetrate both crusts, and both work and initial rigidity). Sensory acceptability was not different ($P < 0.05$) between the soaked product and a commercial sample.

Keywords: French fries; Oil uptake; NaCl absorption; Texture; Sensory analysis

1. Introduction

Deep-fat frying is one of the oldest processes of food preparation and consists basically in immersion of food pieces in hot oil. The high temperature causes an evaporation of the water, which moves away from the food and through the surrounding oil. Oil is absorbed by the food, replacing some of the lost water (Oliveira, Pereira, & Oliveira, 1994). The aim of deep-fat frying is to seal the food by immersing it in the hot oil so that all the flavors and the juices are retained by the crisp crust (Moreira, Palau, & Sin, 1995). French-fries are among the major items of fried foods and amount to 44% of potatoes processed in the US. (Moreira, Castell-Pérez, & Barrufet, 1999). This potato-based product is made from potato strips aproximately 1×1 cm^2 in cross section area and 6–7 cm in length (Lesinska & Leszczynski, 1989).

During the frying process, the physical, chemical, and sensory characteristics of the food are modified. Texture, color and oil content are the main quality parameters of french fries. Good quality french fries must have a crispy crust of about 1–2 mm, where most of the oil is located, and a moist, soft center, like a cooked potato (Aguilera, 1997; Moreira et al., 1999). French fry color is the result of the Maillard reaction which depends on the content of superficial reducing sugars and the temperature and time of frying (Marquez & Añón, 1986). Oil content has been a main concern for food processors from an economic point of view, and for consumers from a healthy one. Processors have identified some ways to control oil uptake, as explained later.

In the french fry process, raw potatoes are washed, peeled, sorted, and cut into strips. Then, the strips are blanched in hot water and dehydrated with warm air to a moisture content of aproximately 60% on wet basis. After this, the potato strips are fried in hot oil (170–190 °C), cooled in ambient air and finally frozen and packaged. The blanching step reduces the oil absorption by gelatinization of the surface starch (Califano & Calvelo, 1987). Air dehydration leads to a lower moisture content which also reduces the oil absorption (Talburt, Weaver, Reeve, & Kueneman, 1987). The blanching and the air drying steps allow for a reduced amount of oil in the final product. This condition can be achieved by increasing the frying oil temperature (Talburt et al., 1987).

Due to public health concerns, there is a strong demand to reduce the oil content of fried foods (Moreira & Barrufet, 1999; Ni & Datta, 1999). In recent years, several procedures have been proposed to reduce

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the amount of absorbed oil. El-Nokali and Hiler (1992) considered a frying process in which the oil contained 0.5–2% hydrophobic silica, which formed an impervious film on the potato strips. Rubnov and Saguy (1997) added fructose to a restructured potato product which resulted in a change of the surface properties, with a reduction of the absorbed oil. Williams and Mittal (1999) used gellan gum to coat samples so that the resulting film reduced the oil absorption.

Since salt is usually added to french fries prior to consumption, soaking them in a sodium chloride solution prior to frying may be a suitable process which can also maintain sensory quality of the product despite some expected textural changes (Andersson, Gekas, Lind, Oliveira, & Öste, 1994; Blahovec, Vacek, & Patocka, 1999). The objective of this work was to study the quality parameters of french fries obtained by frying potato strips previously soaked in NaCl solutions.

2. Materials and methods

2.1. French fry preparation

Potatoes (*Solanum tuberosum*) of the Desiree variety were grown in Chile in 1998. They were stored in darkness at 8 °C at the research facilities until processing. Tubers were washed, sorted, peeled and cut along the long axis by means of a hand-operated french fry cutter into 7×7 mm strips ca. 70 mm in length. In order to minimize enzymatic browning, the strips were dipped in a solution of sodium acid pyrophosphate (0.75% w/w), blanched in the same solution for 8 min at 75 °C and cooled to 25 °C. Blanched potato strips were placed in a stainless steel basket and soaked for 20–50 min in NaCl solution (3, 5 or 7% w/w in tap water) at 25 °C in a thermostatically controlled water bath (Blue M) with continuous agitation (30 rpm) and a ratio of NaCl solution to potato strips of 8:1 (w/w). Strips were rinsed quickly (10 s) in three different beakers containing tap water, with a ratio of water to potato strips of 8:1 (w/w), and gently blotted dry with absorbing tissue paper in order to remove the surface solution. The strips were then arranged on a tray in one single layer and dried in a convection oven (Memmert, model ULM 500) at a dry bulb temperature of 60±1 °C and an air speed of 1±0.1 m/s until a final moisture content of 60±0.1%. The strips were deep-fried in refined, non-hydrogenated sunflower oil (Chef™, Coprona, Chile) in an electric filter fryer (Moulinex Clean Air T45) at 180 °C. A batch size of 200 g of fries in 2.5 l of oil was chosen (Du Pont, Kirby and Smith, 1992). After frying, the samples were held wrapped for 5 min on absorbing tissue paper prior to testing.

For acceptability testing, the process was slightly modified in order to simulate processing and storage conditions of commercial french fries: a short frying step of 1 min at 180 °C was included after the soaking process, then, the samples were deep frozen in an air convection freezer at −25 °C for 3 h and held at −18 °C for 30 days. Prior to testing, the samples were fried for 4 min at 180 °C. Commercial french fries (Maggi™, Nestlé, Chile) were prepared according to manufacturer instructions (frying time of 5 min at 180 °C and NaCl addition of 0.5%).

Table 1
Experimental runs according to factorial design 2^2 with three center points, in order to determine the best soaking conditions

Experimental run	NaCl (%)	Time (min)
1	3	20
2	7	20
3	3	50
4	7	50
5	5	35
6	5	35
7	5	35

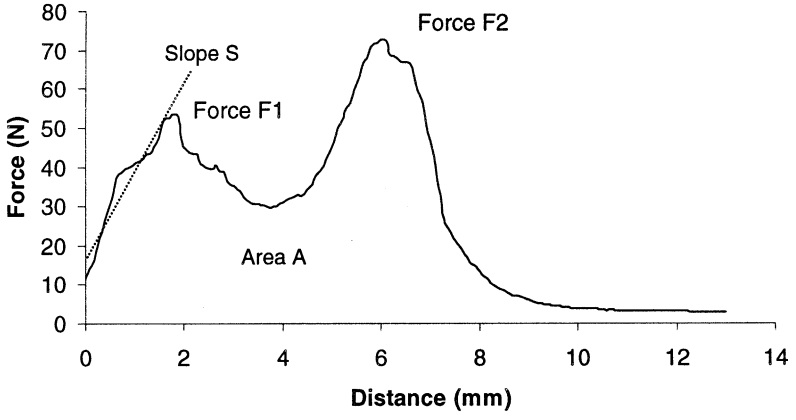

Fig. 1. Typical texture profile obtained for fried potato strips.

2.2. Optimization of the soaking conditions

In order to optimize the immersion time and NaCl concentration of the soaking process on the sensory attributes of the samples, a factorial design of 2^2 type with three center points was carried out (Table 1). The responses were obtained by a trained panel of seven members using a quality scoring test (color, flavor, texture, overall quality and off flavors/odors) on a nine-point numerical scale in which 9 = very good, 1 = very bad (ASTM E 466–72, 1972), and a quantitative descriptive analysis on 10-cm nonstructured linear scales anchored at both ends. The following descriptors and their anchor terms were chosen in agreement with the panelists: saltiness (none–strong), crispness (not crispy–very crispy), springiness (not springy–very springy), remaining oiliness (none–strong) and aftertaste (none–strong). The panelists were previously selected and trained according to standard ISO 8586–1:1993(E) (1993) and familiarized with the product and its attributes in four sessions, in which they were introduced to references for the different intensities of the sensory descriptors.

2.3. Changes of instrumental parameters during the frying process

The effect of the soaking step on texture, color, moisture content and oil absorption was measured during the frying process. For this purpose, analyses were performed on samples prepared under the best conditions of soaking time and NaCl concentration found in the optimization of the soaking conditions, and on control samples fried without soaking. During frying, duplicate samples were taken every minute until completing 6 min of total frying time.

French fry color was measured using a Minolta Chromo Meter CR 200b attached to a data-processor DP-100 using the CIE 1976 L^*, a^* and b^* color scale. Three replications were carried out at 25 °C on three different locations of each slice: the center point and both ends.

Texture was measured using a texture analyzer TA.XT2i (Stable Microsystems, UK) interfaced with a data processor Texture Expert version 1.0 (Stable Microsystems, 1995). A multiple puncture probe,

Table 2
Significance of the factorial design effects (salt concentration and soaking time) on the sensory attributes

Sensory attribute	Significant effects	Significance level	Effects direction
Saltiness	salt	0.0135	as > salt > saltiness
Crispness	n.s.	–	–
Springiness	n.s.	–	–
Remaining oiliness	time, salt	0.0043, 0.0479	as < time > oiliness, as < salt > oiliness
Aftertaste	n.s.	–	–
Color quality	n.s.	–	–
Flavor quality	n.s.	–	–
Texture quality	time	0.0201	as > time > texture quality
Overall quality	n.s.	–	–
Odd flavor/odor	n.s.	–	–

n.s., non significant ($P > 0.05$).

Table 3
Sensory analysis of the soaked french fries (3% NaCl and 50 min) and the control sample (without soaking)

	Soaked fries[a] (3% NaCl and 50 min)	Control sample[a]
Descriptive analysis (10-cm unstructured scale)		
Saltiness	5.5±0.99[b]	5.4±1.33[b]
Crispness	4.8±1.22	4.4±1.79
Springiness	1.3±0.85	1.6±1.33
Remaining oiliness	5.5±1.32	5.9±1.22
Aftertaste	5.0±0.43	4.3±1.19
Quality scoring (nine point numerical scale)		
Color quality	6.9±0.70	6.1±0.94
Flavor quality	5.8±1.48	5.9±1.13
Texture quality	5.5±1.41	5.6±1.41
Overall quality	6.1±1.27	5.6±1.54
Odd flavor/odor	2.3±0.74	3.3±1.46

[a] No significant differences ($P < 0.05$) were found for any of the measured attributes.
[b] Means±95% confidence limits.

known as multiple chip rig, was employed. This probe is especially designed for french fries, and measures the resistance to penetration on 10 strips simultaneously. Each strip is punctured with two probes (2 mm in diameter) at 2 cm from each end. A crosshead speed of 1.7 mm/s and a probe depth of 15 mm were selected, and the measurements were carried out on the strips at 60±2 °C, after frying. A typical graph is shown in Fig. 1, which is a composite of 20 individual punctures of 10 strips. Four parameters were chosen as texture indicators: the hardness to penetrate the upper crust (F1), the force to go through the lower crust (F2), the initial slope (S), which represents rigidity, and the area under the curve (A), which represents the work to penetrate both crusts plus the internal compression (Beltrán, 1999).

The oil content was determined by the method of Bligh and Dyer (1959). The initial proportions of chloroform/methanol/water were 1:2:1.8 and the final proportions 2:2:1.8.

Moisture content was determined by drying 5 g ground samples in duplicate at 105 °C, until constant weight was attained.

2.4. Product acceptability

Acceptability was measured on french fries obtained under the best conditions found in the optimization process, and on local commercial frozen french fries (Maggi™, Nestlé-Chile). Both samples were examined in random order by 35 frequent french-fry consumers, using a nine-point hedonic scale (9 = like it very much, 1 = dislike it very much).

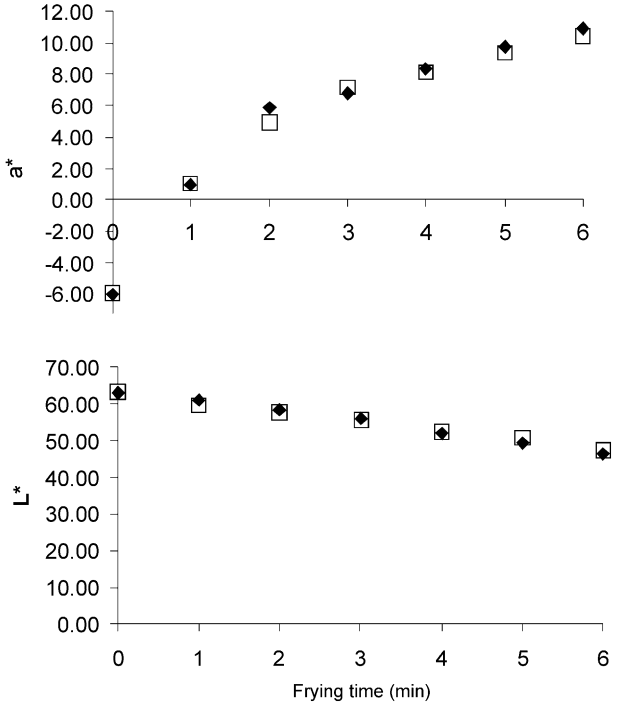

Fig. 2. Changes of the color parameters a^* and L^* during frying time at 180 °C. (□): soaked sample, (◆): control sample.

2.5. Statistical analysis

Data were analyzed by ANOVA, using the statistical software Statgraphics Plus for Windows 4.0 (Statistical Graphics Corp, 1998), with a statistical significance at $P < 0.05$.

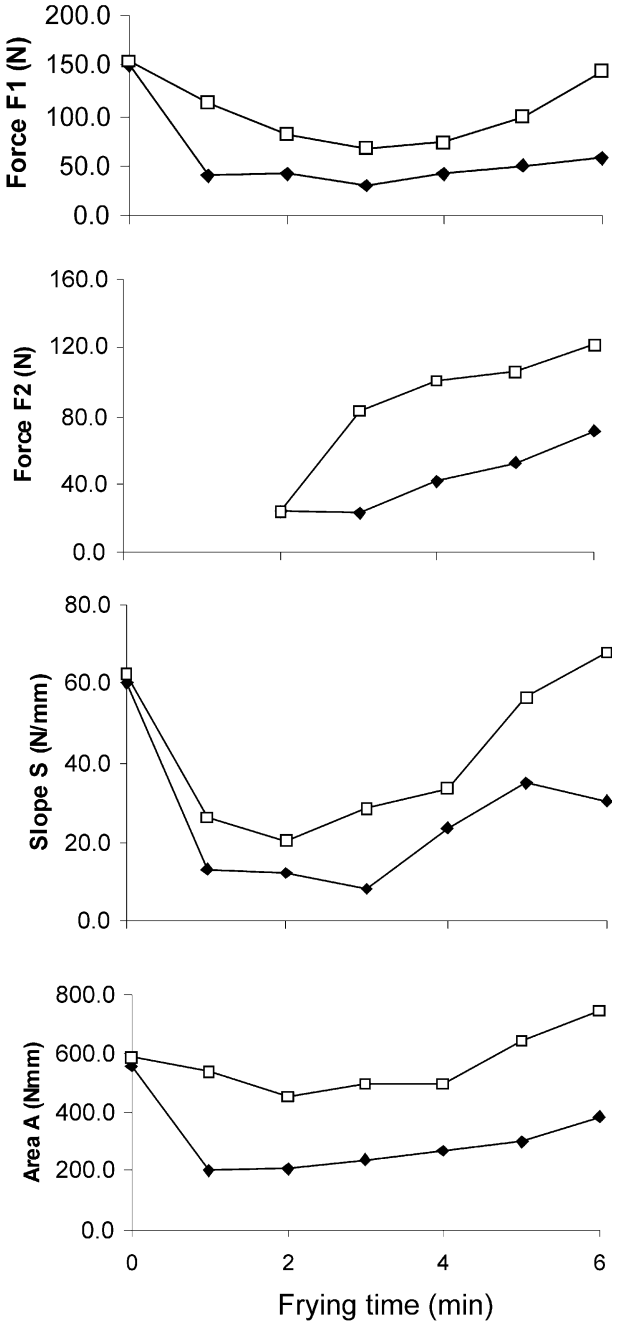

Fig. 3. Force 1 (first peak) and Force 2 (second peak), initial slope S and area A during frying of the soaked sample (□) and the control sample (◆) at 180 °C.

3. Results and discussion

3.1. Optimization of the soaking conditions

The effects of soaking time and concentration of salt solution on the sensory attributes of french fries is shown in Table 2. Soaking time had a significant effect ($P<0.05$) on remaining oiliness and texture quality. A longer soaking time improved texture quality and decreased remaining oiliness, thus the high level of the experimental design (50 min) was chosen as the best soaking time. The concentration of salt solution had a significant effect ($P<0.05$) on remaining oiliness and saltiness. A higher concentration increased saltiness, but reduced the remaining oiliness of the product. As an adequate saltiness of the product is of great importance in its overall sensory quality, the low level of salt concentration was chosen (3% w/w).

Under these soaking conditions (50 min and 3% w/w of NaCl), the moisture content of the potatoes during the soaking process decreased only from 80.2 to 79.6% (wet basis) and the NaCl concentration increased from 0.012 to 0.033 g NaCl/g initial potato.

A comparison of the sensory scores of the soaked french fries with a control sample (Table 3) did not show significant differences ($P<0.05$) for any of the measured attributes, indicating that the chosen soaking time and NaCl concentration led to an acceptable sensory quality in the product.

3.2. Changes of instrumental parameters during the frying process

The evolution of the color parameters L^* and a^* during frying time of the soaked potatoes and those of the control sample (Fig. 2) did not show significant differences ($P<0.05$), indicating that NaCl concentration does not affect the browning process during frying. This result agrees with the sensory evaluation, in which the color scores remained constant for different soaking times and NaCl concentrations (results not shown). At the commercial frying time of 5 min, values of 50.78 ± 1.02 and 9.35 ± 0.92 (average$\pm$standard deviation) were obtained for L^* and a^*, respectively, considered adequate in order to obtain an acceptable color (Marquez & Añon, 1986). Parameter a^* trended higher and L^* trended lower as frying time increased. Parameter b^* remained constant over the frying time for both samples (results not shown).

For the texture analysis, soaked samples showed an increase in the four measured texture parameters compared to the control sample (Fig. 3). The increased hardness of the soaked french fries showed agreement with the results of the factorial analysis, in which the increased soaking time improved the sensory textural quality, probably due to the higher diffusion of the NaCl into the tissue. The force F1 to penetrate the upper crust (Fig. 3), the slope S and the area A decreased at frying times from 1 to 4 min, indicating the beginning of starch gelatinization and softening prior to the formation of a thick and rigid crust. The force F2, to go through the lower layer, started at a frying time of 2 min, showing a progressive hardening due to crust formation and increase in tissue resistance.

The soaking process in NaCl solution led to a lower oil uptake compared to the control sample (Fig. 4), with a 22.2% difference. This trend was also observed in the results of the factorial design, where higher NaCl concentrations and longer soaking periods reduced the remaining sensory oiliness. Rubnov and Saguy (1997) reported, in a study of a restructured potato product, that addition of fructose reduced the oil uptake due to changes of the interfacial tension or to the formation of a thicker crust. The latter explanation shows agreement with the increased hardness found in texture analysis of the soaked french fries. Oil uptake remained constant

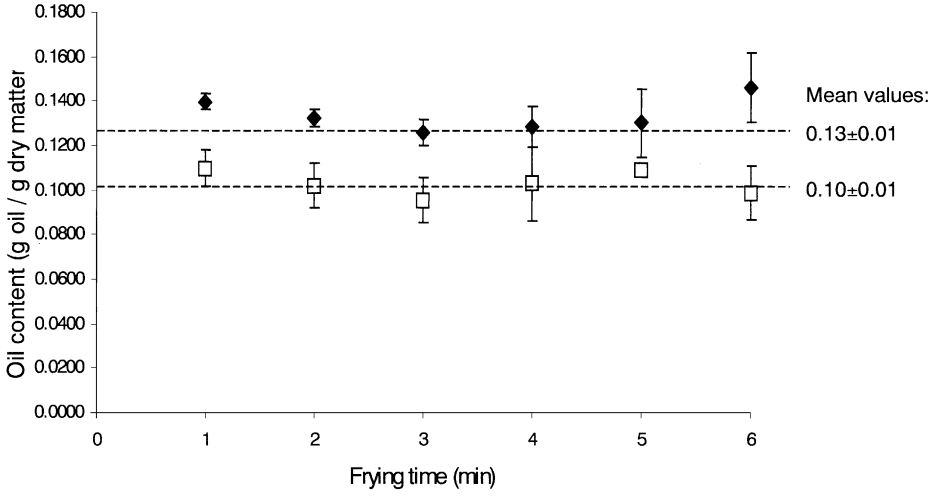

Fig. 4. Oil uptake (g oil/g dry matter) during frying and average oil uptake at 180 °C. (□): soaked sample, (◆): control sample.

Table 4
Sensory acceptability of the soaked french fries and a commercial sample measured on a nine-point hedonic scale with 35 consumers

Sample[a]	Acceptability
Soaked	6.0 ± 0.69[b] (like slightly)
Commercial	6.5 ± 0.57[b] (like slightly)

[a] No significant difference ($P < 0.05$) was found between samples.
[b] Means $\pm$ 95% confidence limits.

from the first minute of frying, confirming that the oil absorption is produced at the beginning of the frying period (Moreira et al., 1999; Ufheil & Escher, 1996).

The moisture loss of soaked potatoes and the control sample during frying did not show significant differences ($P < 0.05$). This finding indicates that the increased hardness and lower oil uptake of soaked potatoes can not be attributed to moisture loss.

3.3. Product acceptability

Both the soaked sample and the commercial product showed a moderate acceptability and did not present significant differences ($P < 0.05$; Table 4).

4. Conclusions

Soaking of potato strips in NaCl solution under the best conditions found (3% w/w NaCl concentration and 50 min soaking time) reduced oil uptake and increased hardness and sensory texture quality of french fries, without modifying color, moisture content nor sensory acceptability. These findings open an interesting possibility in order to produce a healthier product introducing a simple soaking step into the french fries processing line.

Acknowledgements

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References

Aguilera, J. M. (1997). Fritura de alimentos. In J. M. Aguilera (Ed.), *Temas en tecnología de alimentos. Vol 1*. México, D.F: Dirección de publicaciones Instituto Politécnico Nacional.

Andersson, A., Gekas, V., Lind, I., Oliveira, F., & Öste, R. (1994). Effect of preheating on potato texture. *Critical Reviews in Food Science and Nutrition*, *34*(3), 229–251.

ASTM E 466–72, (1972) re-approved. (1978). *Standard recommended practice for determining effect of packaging on food and beverage products during storage*. Philadelphia, USA: American Society for Testing and Materials.

Beltrán, J. (1999). *Análisis instrumental de textura durante la fritura de papas*. Chemical Engineering thesis, University of Santiago de Chile.

Blahovec, J., Vacek, J., & Patocka, K. (1999). Texture of fried potato tissue as affected by pre-blanching in some salt solutions. *Journal of Texture Studies*, *30*, 493–507.

Bligh, E. G., & Dyer, W. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, *37*, 911–917.

Califano, A. N., & Calvelo, A. (1987). Adjustment of surface concentration of reducing sugars before frying of potato strips. *Journal of Food Processing and Preservation*, *12*, 1–9.

Du Pont, M. S., Kirby, A. R., & Smith, A. C. (1992). Instrumental and sensory tests of texture of cooked frozen french fries. *International Journal of Food Science and Technology*, *27*, 285–295.

El-Nokali, E., & Hiler, G.D. (1992), *Process of using silica to decrease fat adsorption*. United States Patent US 5100684.

ISO 8586–1:1993(E). (1993). *Sensory analysis—general guidance for the selection, training and monitoring of assessors—part 1: selected assessors*. Geneva, Switzerland: International Organization for Standardization.

Lesinska, G., & Leszczynski, W. (1989). *Potato science and technology*. New York, USA: Elsevier Science.

Márquez, G., & Añón, M. C. (1986). Influence of reducing sugars and amino acids in the color development of fried potatoes. *Journal of Food Science*, *51*(1), 157–160.

Moreira, R., Palau, J., & Sin, X. (1995). Simultaneous heat and mass transfer during the deep fat frying of tortilla chips. *Journal of Food Process Engineering*, *18*, 307–320.

Moreira, R. G., Castell-Pérez, M. E., & Barrufet, M. A. (1999). *Deep-fat frying: fundamentals and applications*. Maryland, USA: Aspen Publishers.

Moreira, R. G., & Barrufet, M. A. (1999). A new approach to describe oil absorption in fried foods: a simulation study. *Journal of Food Engineering*, *35*, 1–22.

Ni, H., & Datta, A. K. (1999). Moisture, oil and energy transport during deep-fat frying of food materials. *Transactions of the Institute of Chemical Engineers*, *77*(C), 194–204.

Oliveira, J. C., Pereira, P. M., & Oliveira, F. A. (1994). The role of transport phenomena. In R. P. Singh, & F. A. Oliveira (Eds.), *Minimal processing of foods and process optimization*. Boca Raton, USA: CRC Press.

Rubnov, M., & Saguy, I. S. (1997). Fractal analysis and crust water diffusivity of a restructured potato product during deep-fat frying. *Journal of Food Science*, *62:154*, 135–137.

Stable Micro Systems. (1995). *Texture expert for Windows, version 1.0*, UK.

Statistical Graphics Corp. (1998). *Statgraphics plus version 4.0*. USA: Manugistics Inc.

Talburt, W. F., Weaver, M. L., Reeve, R. M., & Kueneman, R. W. (1987). Frozen french fries and other frozen products. In W. F. Talburt, & O. Smith (Eds.), *Potato processing*. New York, USA: Van Nostrand Reinhold/AVI.

Ufheil, G., & Escher, F. (1996). Dynamics of oil uptake during deep-fat frying of potato slices. *Lebensmittel Wissenschaft und Technologie*, *29*(7), 640–644.

Williams, R., & Mittal, G. S. (1999). Low-fat fried foods with edible coatings: modeling and simulation. *Journal of Food Science*, *64*, 317–322.