UNIVERSIDAD SAN FRANCISCO DE QUITO

EFFECT OF VARIOUS DRYING PRE-TREATMENTS ON THE UPTAKE OF OIL DURING THE FRYING OF PLANTAIN CHIPS

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DEDICATORIA

Primeramente, quisiera dedicar esta tesis a mis padres que siempre estuvieron dispuestos a apoyarme y aconsejarme. Sin ellos no podría haber cumplido este sueño de obtener mi título profesional. También quiero dedicar esta tesis a mis hermanos: María Soledad y Diego que han sido y siguen siendo un soporte importante de mi vida. Finalmente, pero no menos importante, dedico esta tesis a mis amigos ingenieros con los que he compartido muchos momentos inolvidables durante estos cinco años de estudios.

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RESUMEN

El objetivo de este estudio fue investigar la influencia del secado por aire caliente como pretratamiento en la producción semi industrial de chifles. Para este propósito fue usada la variedad de plátano barraganete (*Musa paradisiaca* AAB). El experimento contó con 16 muestras que combinaron diferentes temperaturas de secado (50º, 60º, 70º y 80 ºC) y temperaturas de freído (160º, 170º, 180º y 190 ºC). Adicionalmente, se prepararon 4 muestras control, correspondientes a cada temperatura de freído. El contenido de grasa de los chifles fue determinado mediante el método Soxhlet. Los resultados fueron analizados por medio de la Metodología de Superficie de Respuesta, obteniendo un modelo altamente significativo ($p<0.01$). Los datos obtenidos mostraron una disminución en el contenido de grasa para la mayoría de las combinaciones de temperaturas de secado-freído. El experimento comprobó una vez más que la absorción de aceite es menor a mayores temperaturas de freído. Sin embargo, a estas temperaturas se obtienen chifles de color indeseable (amarillo parduzco). Además, se encontró que las temperaturas óptimas de secado se encuentran alrededor de 60 ºC para todas las temperaturas de freído del experimento. Adicionalmente, el estudio proporcionó un modelo matemático capaz de predecir el contenido de grasa en los chifles.

ABSTRACT

The objective of this study was to investigate the influence of hot air drying as a pre-treatment in the semi-industrial production of plantain chips. The plantain variety "Barraganete" (*Musa paradisiaca* AAB) was used for this purpose. The experiment had sixteen different combinations of drying (50º, 60º, 70º and 80 ºC) and frying temperatures (160º, 170º, 180º and 190 ºC). Additionally, four control samples were produced for each frying temperature. Fat content was determined by Soxhlet method. Results were analyzed by Response Surface Methodology, giving a highly significant model ($p < 0.01$). Data showed a decrease of fat content for almost all drying – frying combined temperatures. The experiment proved once again that less oil is absorbed at higher frying temperatures. However, at these temperatures the colour of the chips is undesirable (yellow brownish). Optimal drying temperatures were found around 60 ºC for all frying temperatures. Furthermore, a mathematical model to predict fat content is given.

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INTRODUCTION

Snacks are one of the most consumed foods worldwide. Plantain chips are snacks consumed mostly in Africa, Latin America and Asia (Rojas, 2007). They are produced by using a deep-fat frying process which can cause obesity and cardiovascular diseases when consumed in excess due to their high fat content. According to Rimac-Brnčić *et al.* (2004), deep fat fried products may contain up to 45% of fat.

When frying, a process of heat and mass exchange occurs. Several chemical and physical changes can also occur, and include starch gelatinization, protein denaturation, crust formation, Maillard reaction and water vaporization (Alvarez & Morillo, 1999; Mellema, 2003). The latter occurs when free water in the tissue of the food boils and escapes leaving pores on the surface. Afterwards, some of these pores may be filled with oil that partially replaces the water lost, giving fries their characteristic crispness and flavor (Mellema, 2003). Bouchon *et. al* (2003) identified three oil fractions retained in deep-fat fried foods: structural oil (absorbed during frying), penetrated surface oil (enters during cooling), and surface oil (remains on the exterior part of the food). The first represents just 5% of the total oil absorbed, while the penetrated surface oil corresponds to the majority of the absorbed oil, about 64% (Moreno & Bouchon, 2008; Mellema, 2003). Thus, after frying a shaking procedure is highly recommended.

Several factors influence oil uptake. These include: frying conditions (temperature and time), physico-chemical properties and pre-treatments of raw food, and the characteristics of the oil used for frying (primarily origin and composition) (Rimac-Brnčić *et al.,* 2004). Based on this knowledge, several methods to reduce oil absorption have been investigated, including vacuum frying (Song *et al*., 2007) and various pre-treatments such as: the use of osmotic substances (salt and glucose) (Ikoko & Kuri, 2007); the application of edible coatings (corn zein, long fiber cellulose, starch, modified starch, gellan gum, methylcellulose and hydroxypropylmethylcellulose) (Moreno & Bouchon, 2008; Garca *et al*., 2002); and the combination of blanching in a solution of calcium chloride with an imnmersion in hydrocolloids (alginates, carboxymethylcellulose, and pectin) (Singthong & Thongkaew, 2009). These methods are based on reducing the permeability of the surface through structural changes to the food tissue. However, these are not suitable for industrial purposes due to their high cost and their complexity when adapting to a mass production.

Drying as a pre-treatment has demonstrated to be effective in reducing oil absorption in fried potatoes (Pedreschi & Moyano, 2005). As with other pre-treatments, it works by lowering the permeability to oil of the external food layer. Methods for increasing water loss include hot air treatment, microwave vacuum drying and freeze drying (Moreno & Bouchon, 2008; Song *et al*., 2007). Studies show that this procedure can also be used as a post-frying treatment (using hot air or super-heated steam) as a method for reducing penetrated surface oil (Moreno & Bouchon, 2008).

The aim of this study was to reduce oil absorption in plantain chips by using hot air drying as a pre-treatment. Finding the ideal combinations of drying-frying temperatures for reducing the greatest amount of fat content was the main objective. Experiments were performed at a pilot plant scale duplicating the conditions used by the Exotic Blends Company in the manufacture of their plantain chips. Therefore, this method should be easily adaptable to factory conditions.

MATERIALS AND METHODS

The Barraganete variety of plantain (*Musa paradisiaca* AAB, (SICA, 2009)) was provided by the Exotic Blends Company from plantations located in Santo Domingo de los Tsáchilas, Ecuador, and represents one variety used in the production of plantain chips. Only green (immature) fruits were processed. The oil used for frying was palmolein (Danolin Fri 3317, provided by Danec SA, Ecuador), which is frequently used for frying of plantain snacks. All chemicals (analytical grade) were provided by the Department of Food Engineering of the College of Agriculture, Foods and Nutrition, USFQ.

Preparation of plantain chips

Plantains were peeled manually and sliced using a Japanese Mandolin (Benriner, Japan) to a thickness between 2-3 mm, the same thickness of plantain chips processed by the The Exotic Blends Company. Slices were weighed using a Mettler Toledo balance (Model PB3002-5), placed on perforated stainless steel trays, and transferred to a forced hot air dryer (Proingal, model SB100, Ecuador). The slices were dried at either 50, 60, 70 or 80 ºC (± 2 ºC) until they lost 10% of their initial weight. Drying times were 6 min 35 sec, 5 min 20 sec, 4 min 35 sec, and 3 min 35 sec respectively. Frying was carried out in a liquid gas fired Basket Fryer (American Range, model AF-45, USA), thermostatically controlled to maintain the set frying temperature. Plantain chips dried at each of these temperatures were fried at: 160, 170, 180 and 190 ºC, for 4, 3.5, 3, and 2.5 minutes, respectively. Frying times were determined from preliminary experiments. The chip-to-oil ratio was 1:5 by weight, the same ratio used by The Exotic Blends Company. Control samples were prepared for each frying temperature. After frying, excess oil was removed by shaking the baskets manually and the chips were placed on a rack to cool. Samples were stored in sealed, low density polyetheylene bags and kept at room temperature (22 ºC approximately) until analyses were performed.

Analyses

Samples were finely ground with a Toastmaster Coffee Grinder (Model 1119). Then, using an analytical Mettler Toledo balance (Model AB204-S), five grams were weighted directly into cellulose extraction thimbles (Whatman, 25 mm ×100 mm, UK), and fat was extracted according to the method for Soxhlet extraction (AOAC, 1995). A clean 250 mL flat bottom flask (Pyrex Corning 24/40) was weighted on an analytical balance and 130 mL of n-hexane GR (Merck, Purity 96%) were added. Extraction was performed for 3 hours using Soxhlet apparatus (Electrothermal heating surface; Pyrex Corning condensing and extraction tubes). The n-hexane then was removed using a rotary evaporator (Büchi Rotavapor, model R-200) and the residual solvent removed by placing the flasks for 1 h in an electrical oven at 90º ± 2 ºC (Precision, model 602101406). Flasks containing extracted fat were weighted on the analytical balance. Samples were analyzed in triplicate.

Calculations

Fat content

Fat content was calculated by the following formula:

$$\text{Fat Content (\%)} = \frac{\text{Weight of flask with extracted fat (g)} - \text{Weight of empty flask (g)}}{\text{Sample weight (g)}} \times 100$$

Statistical Analysis

For each sample, an average for the fat content was calculated. Outliers were identified by Grubb's test ($p < 0.01$) (National Institute of Standards and Technology, 2009), and then excluded from the analysis. Data were analyzed by Response Surface Methodology to examine interaction between variables using Design Expert 7.1.5 Software (Stat-Ease Inc, USA). Results showed a highly significant model ($p < 0.01$). A 3D response surface graph was provided by the same software to help visualize the results. At the same time, a mathematical model was developed to predict fat content in the final product under different frying and drying conditions.

RESULTS AND DISCUSSION

Oil content for control samples ranges from 24-30% (Table 1). These data are consistent with that observed in the Exotic Blends factory (Juan Pablo Molina, personal communication, 2009). Hot air drying as a pre-treatment reduces oil absorption in plantain chips in most cases (Table 1). Plantain dried at 70 ºC and fried at 190 ºC showed the least absorption of oil, while plantain dried at 80 ºC and fried at 160 ºC exhibited the highest fat content. Plantain fried at higher temperatures such as 180 ºC and 190 ºC showed less fat content than the other treatments did for most of the drying temperatures. These results support previous studies which reported less oil absorption at higher frying temperatures (Rimac-Brncic *et al.,* 2003; Pedreschi & Moyano, 2005; Ufheil & Escher, 1996). However, high frying temperatures lead to an undesirable yellow brownish chip color in contrast to the bright yellow of chips fried at 160 ºC and 170 ºC.

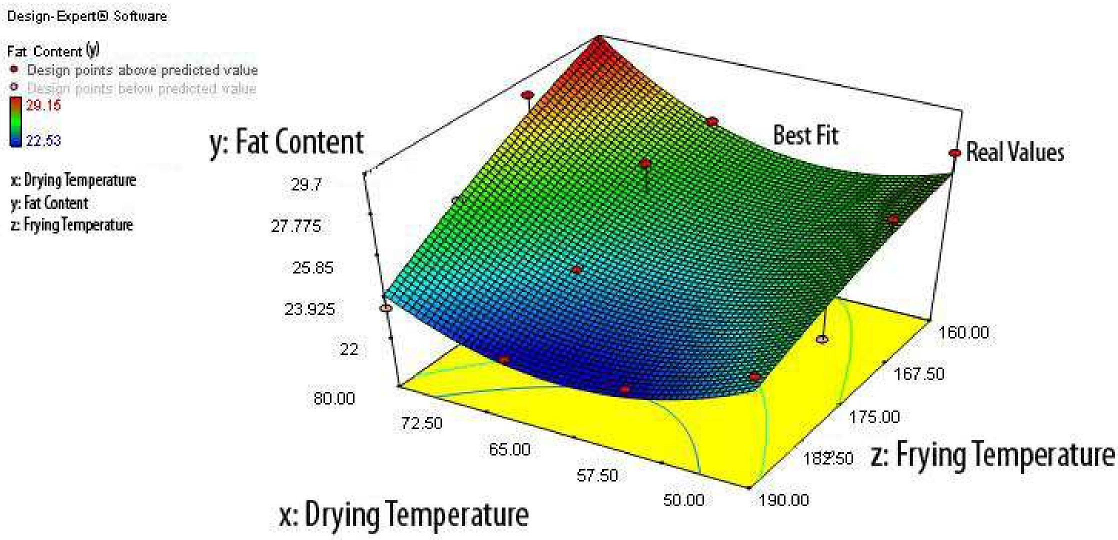
Table 1. Average fat content in plantain chips.

Treatment		Average Fat Content (%)
Frying temperature (°C)	Drying temperature (°C)	
160	None	29.36
160	50	27.79
160	60	24.90
160	70	26.83
160	80	29.15
170	None	30.41
170	50	27.03
170	60	23.84
170	70	26.96
170	80	28.89
180	None	25.79
180	50	23.96
180	60	23.70
180	70	24.27
180	80	26.18
190	None	24.34
190	50	25.04
190	60	22.71
190	70	22.53
190	80	23.48

For most of the frying temperatures, there is a tendency to have higher oil content at drying temperatures of 50°, 70° and 80 °C when comparing to the ideal (around 60 °C). This could be explained with the fact that plantain starch begins to gelatinize at 59.3 °C (Pérez-Sira, 2006). Previous studies showed that swelling of starch inhibits oil uptake during deep-fat frying (Hiu, 2006). At 50 °C starch is not still gelatinized; therefore, fat absorption is higher. On the other hand, even though at 70° and 80 °C starch is gelatinized, the high absorption of oil is probably due to the great quantity of small narrow pores that are formed during drying process (Mellema, 2006; Hiu, 2006).

The response surface model and the information given by Design Expert 7.1.5 Sofware is presented in Figure 1. The resulting model is highly significant ($p > 0.01$) and shows that low frying temperatures (160-168 ºC) combined with drying temperatures of 76-80 ºC caused the largest amount of oil absorption in plantain chips. In contrast, the lowest amounts of oil absorption occurred at frying temperatures in the range of 182-190 ºC and 54-76 ºC of drying.

Figure 1. Response surface model for fat content (%) as a function of drying and frying temperatures.



The equation generated by Design Expert 7.1.5 Software to predict the percentage of fat in fried plantain chips is:

$$\boldsymbol{Fat\,\% = 1.93475 - 0.64303A + 0.61317B - 3.408E^{-3}AB + 9.8625E^{-3}A^2 - 1.5E^{-3}B^2}$$

where:

A = drying temperature (50º - 80 ºC)

B= frying temperature (160º - 190 ºC).

From this equation, optimal drying temperatures to reduce the fat content at each frying temperature can be calculated (Table 3). Optimal drying temperatures are between 59.5º and 63.7 ºC.

Table 3. Optimal drying temperatures and predicted fat content at each frying temperature

Frying Temperature (ºC)	Optimal Drying Temperature (ºC)	Expected Fat Content (%)
160	60	25.85
170	62	24.95
180	63.7	23.69
190	59.5	22.41

CONCLUSIONS

This study demonstrated that hot air drying is an effective pretreatment to reduce oil uptake during deep-fat frying of plantain chips. It was found that the optimal drying temperatures were between 59.5º and 63.7 ºC for all frying temperatures in the range of 160º-190 ºC. Using response surface analysis, the lowest content of fat (22.41%) was obtained at temperatures of 59.5º and 190 ºC of drying and frying respectively. It was once again proven that at higher frying temperatures less oil is absorbed. Still, chips fried at these temperatures (180º -190 ºC) had a brownish yellow unacceptable color. Further research involving a consumer preference sensory study is recommended to evaluate acceptance for reduced fat plantain chips.

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