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Effects of processing conditions on the quality of vacuum fried cassava chips (*Manihot esculenta* Crantz)

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ABSTRACT

Concern for the nutritional quality of chips is growing due to rising consumption, motivating research and development of new snack products that contribute to a lower calorie and fat intake in the diet while retaining their good flavor and facility of consumption. The objective of this study was to investigate the behavior of cassava chips, blanched or unblanched and processed under either atmospheric or vacuum frying conditions, in order to determine the influence of these treatments on mechanical and acoustic parameters, optical properties and oil absorption. Vacuum frying trials (17 kPa) were conducted at 120, 130 and 140 °C and compared with frying at atmospheric pressure (101.3 kPa) at 165 °C. Pre-blanching brings a considerable improvement in the color of the vacuum-treated samples and less oil absorption. Vacuum frying pre-blanched cassava chips may be an alternative to atmospheric frying since it improves the color of the samples, reduces the oil gain and maintains crispness. The treatment at 130 °C under vacuum conditions after pre-blanching achieved the best results.

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1. Introduction

Cassava (*Manihot esculenta* Crantz) is an extensively cultivated tuber crop and its consumption is considered part of the culture of many developing countries. Cassava is a staple food for millions of people in the tropical regions of Africa, Latin America and Asia (Nambisan, 2011). A major factor limiting the food value of cassava is the presence of cyanogenic glucosides (linamarin and lotaustralin), which liberate acetone cyanohydrin and hydrogen cyanide upon hydrolysis by the endogenous enzyme, linamarase (Conn, 1979). The presence of these toxic compounds in cassava and its food products is a cause of concern because of their possible effects on health. It is therefore necessary to eliminate/reduce their levels in tubers to a minimum in order to make cassava safe for consumption. Major research efforts to eliminate/reduce cyanoglucosides have focused on developing acyanogenic cassava varieties by breeding, controlling its metabolism, and processing to remove cyanogens. Many so-called "sweet" varieties have very low levels of cyanogenic glucosides and can be consumed safely after a thermal process. Traditional processing methods include boiling, blanching, drying, parboiling and drying, baking, steaming, frying and preparing flour. These processes result in cyanide losses ranging from 25% to 98% (Nambisan, 2011). To remove cyanogens from cassava, increase the value of this crop and open up new markets, new uses for cassava have been sought, once of which is fried cassava chips (Grizotto & De Menezes, 2002; Vitrac, Dufour, Trystram, & Raoult-Wack, 2002).

Numerous studies have revealed that excess consumption of fat, one of the main components of deep-fried food, is a key dietary contributor to coronary heart disease and perhaps to cancer of the breast, colon and prostate (Browner, Westenhouse, & Tice, 1991). In recent years, consumer preferences for low-fat and fat-free products have been the driving force behind the snack food industry's efforts to manufacture products with lower oil contents that still retain a desirable texture and flavor (Garayo & Moreira, 2002). Several processes have been developed to allow companies to manufacture reduced-fat products that possess the desired quality attributes of deep fat fried food whilst preserving their nutritional properties. These include alternative technologies such as extrusion, drying, and baking, which may be applied to raw food or to formulated products. Unfortunately, none of them has been as successful as expected because they are still unable to impart the desired quality attributes of deep fat fried food, such as flavor, texture, appearance, and mouthfeel (Dueik, Robert, & Bouchon,

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2010). For this purpose, vacuum frying may be an option for producing fruits, vegetables and other products with a low oil content and the desired texture and flavor characteristics. Vacuum frying is defined as the frying process that is carried out under pressures well below atmospheric levels, preferably below 50 Torr (6.65 kPa) (Nunes & Moreira, 2009). The lower pressure reduces the boiling points of both the oil and the moisture in the foods. Vacuum frying possess some advantages that include: (1) can reduce the oil content of the fried product, (2) can preserve the natural color and flavors of the product due to the low temperature and oxygen control during the process, (3) has fewer adverse effects on oil quality (Shyu, Hau, & Hwang, 1998), (4) decreased acrylamide content (Granda, Moreira, & Tichy, 2004), and (5) preservation of nutritional compounds (Da Silva & Moreira, 2008). Vacuum frying has been studied in various types of food, such as potato (Dueik & Bouchon, 2011; Garayo & Moreira, 2002), banana (Yamsaengsung, Ariyapuchai, & Prasertsit, 2011), jackfruit (Diamante, 2008), carrots (Dueik et al., 2010), pineapple (Pérez-Tinoco, Perez, Salgado-Cervantes, Reynes, & Vaillant, 2008) or vegetables chips (Da Silva & Moreira, 2008). However, no mention of using cassava to produce vacuum-fried chips for human consumption was found in the literature.

Blanching is a food preparation process in which the food is plunged into boiling water or steam. It is used to reduce enzyme activity. It is one of the most widely used methods to prevent browning (Liu-Ping, Min-Zhang, & Mujumdar, 2005; Shyu & Hwang, 2001; Shyu, Hau, & Hwang, 2005) and to leach soluble sugars (Krokida, Oreopoulou, Maroulis, & Marinos-Kouris, 2001). Xin, Zhang, Xu, Adhikari, and Sun (2015) reported that in potato chip processing, a blanching step before frying improves the color and texture and, in some cases, reduces the oil content by gelatinizing the surface starch. Troncoso, Pedreschi, and Zúñiga (2009) suggest that blanching and blanching combined with air drying significantly influence instrumental parameters such as color (L^*,a^*, b^* and ΔE) and flavor, as well as the overall quality of the potato chips, but that the best flavor is obtained by vacuum frying the potato chips without pretreatment.

The objective of this study was to develop high-quality cassava chips using a blanching pretreatment and vacuum frying as the process treatments and to study changes in color, mechanical and acoustic parameters, oil content and moisture, in order to identify the potential of vacuum frying for producing novel cassava snacks that follow the new health trends.

2. Materials and methods

2.1. Sample preparation

Fresh cassava (*M. esculenta* Crantz) from Costa Rica was purchased from a local market in Valencia (Spain). It was verified that the pieces were whole, healthy (free of mold, rots or deterioration) and free of any strange odor. The whole cassavas were stored at room temperature prior to use. After peeling, the cassavas were cut into 1.5–1.8 mm thick slices with a slicer (Siemens MS70001, Siemens, Spain). The cassava slices were divided in two groups. One of them received a blanching pretreatment before being fried (B) and the other group was fried without pretreatment (UB).

2.2. Blanching treatment

Blanching was carried out in a thermostat-controlled water bath (Precisterm S-386, Selecta, Barcelona, Spain) at 70 °C for 10 min (Taiwo & Baik, 2007). After treatment, excess water on the product surface was removed by gently blotting with absorbent paper (Krokida et al., 2001).

2.3. Frying treatments

Two frying treatments, atmospheric frying and vacuum frying, were used. Sunflower oil (Hacendado, España S.A., Sevilla, Spain) was used for frying. The oil/cassava frying ratio was 20:1 g/g in all treatments. Atmospheric frying (AF) was carried out at an oil temperature of 165 °C, since this is within the range of temperatures normally used (between 150 °C and 180 °C) (Choe & Min, 2007). For the atmospheric frying experiments, a commercial deep fat fryer was used (Movilfrit, Barcelona, Spain). Vacuum frying was carried out at 17 kPa in a vacuum fryer (Gastrovac, International Cooking Concepts, Barcelona, Spain), at three oil temperatures (120, 130 and 140 °C). After frying and before vacuum rupture, the cassava chips were removed from the oil and centrifuged for 2 min to avoid oil impregnation (Da Silva & Moreira, 2008). The atmospheric and vacuum frying treatment times studied ranged from 1 to 10 min (at 1 min intervals). After frying, the cassava chips were cooled at room temperature, packed in polyethylene pouches (Cryovac® HT3050, Cryovac Sealed Air Corporation, Barcelona, Spain) and stored at 25 °C before analysis.

2.4. Proximate composition

The moisture content of the cassava chips was measured by drying in a vacuum oven at 70 °C at 10 kPa. Ground samples (5 g) were dried to a constant weight. The moisture content was calculated from the weight difference between the original and dried samples and expressed as dry base. Three samples were used for each time and temperature.

The total fat content of the dried cassava chip samples (5 g) was extracted with petroleum ether (BP 40–60 °C) for 4 h in a Soxtec System 2055 Tecator extracting unit (FOSS, Hillerød, Denmark) and gravimetrically determined. Three samples were used for each time and temperature.

2.5. Characteristics of the fried product

The weight loss was calculated as the percentage weight difference between the raw and fried samples relative to the weight of the raw cassava slices. Before weighing, the samples were dried with absorbent paper in order to remove the surface water from the fresh cassava slices and the surface oil from the fried ones. The samples were weighed with a Mettler Toledo model PB303-S analytical balance (Mettler Toledo GmbH, Greifensee, Switzerland). Three samples were used for each time and temperature.

A TA-XT2 texture analyzer (Stable Micro Systems Co Ltd, Godalming, UK) with version 4.0.13.0 of the Texture Expert data analysis program (2009) and a P/0.5S spherical probe measuring ½ inch in diameter (Stable Micro System) was used to determine the breaking force, area under the curve and number of peaks. The samples were placed on a HDP/CFS platform (Crisp Fracture Support Rig). The test parameters were: test speed 1 mm/s, activation force 5 g, distance of sound 3 mm. All the numerical results were expressed in grams. For the study of crispness, a surrounding sound detector fitted with a Bruel and Kjaer microphone (8 mm diameter) was used (Chen, Karlsson, & Povey, 2005; Varela, Chen, Fiszman, & Povey, 2006). The microphone was placed at a 45° angle at a distance of 4 cm from the center of the sample. The environmental acoustics and noise were filtered with a high-step filter (step size 1 kHz). The data acquisition rate was 500 points per second for both the force and the acoustic signals. All the tests were performed at room temperature in a laboratory with no special soundproof facilities. Twenty replications were performed for each kind of cassava chip. The force/displacement and sound pressure level (SPL)/

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