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Analysis of wheat gluten and starch matrices during deep-fat frying

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ABSTRACT

An important quality parameter of fried food is the amount of oil uptake, which is incompatible with recent consumer trends towards healthier food. The oil penetration mechanism is not fully understood but study of formulated products is a good way to elucidate the role of the food matrix in oil absorption.

In this context, the oil absorption capacity of a restructured matrix, made with native wheat starch and vital wheat gluten, was examined. Four different product formulations were analysed, using 2 levels of gluten content (8% and 12% d.b.) and 2 levels of water content (38% and 44% w.b.). Dough was sheeted into 2 thicknesses (1 and 2 mm) and cut into discs that were either directly fried or fried after predrying with dry air (2 min at 150 °C).

Results showed that gluten had a predominant role in the structure, making the dough more elastic and less permeable to oil absorption. High gluten content resulted in lower oil uptake in products with low moisture content. Overall, predried discs absorbed, on average, half of the oil of undried samples. Interestingly, even though predried products with high gluten content had a higher moisture content before frying, they absorbed a low amount of oil, suggesting that oil uptake is not clearly related to the amount of moisture lost but rather to product microstructure.

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1. Introduction

Food processing is facing new challenges, which include providing, in addition to microbiologically safe and high quality foods, products that fulfil the new demands of well-informed consumers. People ask that products contribute to their wellness and health, but they also require specific textures, flavours, colours, and certainly, a consistent food. That is, consumers expect minimal variations in food products from batch to batch. This product-driven process engineering era, as coined by Aguilera (2006), requires the building of controlled structures and therefore, understanding of the functionality of the structural elements prior to or during processing. In the light of this approach, product formulation appears as a good alternative for developing new products with controlled attributes. Accordingly, formulated products are gaining importance in the snack industry as a good alternative to the use of raw materials, because of the advantages of reproducibility, uniformity and lack of defects (Gebhardt, 1996) in contrast, for instance, to potato, whose heterogeneity can cause major variations in final products (Baumann & Escher, 1995).

Deep-fat frying is one of the oldest and most common unit operations used in the preparation of processed foods, and is especially suited to develop snacks with unique flavours and textures. It can be defined as a process for cooking foods, by immersing them in edible oil, at a temperature above the boiling point of water, usually between 160 and 190 °C, under atmospheric conditions (Farkas, 1994). The process involves simultaneous heat and mass transfer, which cause significant microstructural changes to both the surface and the body of the product. Heat transferred from the oil into the food causes protein denaturation, starch gelatinisation, water vapourisation, crust formation and colour development, which are typical phenomena of the combined effects of multiple-order chemical reactions (Singh, 1995). Mass transfer is characterised by the loss of water from the food as water vapour and the movement of oil into the food (Dobraszczyk, Ainsworth, Ibanoglu, & Bouchon, 2006). It is not clearly understood how oil uptake takes place, but there is some experimental evidence showing that water loss and oil absorption are asynchronous phenomena. It has been proposed that, during frying, the vigorous escape of water vapour would generate a barrier to prevent oil migration into the porous structure and, as a consequence, oil absorption would be limited during most of the immersion period. As a result, oil uptake would be essentially a surface-related phenomenon resulting from the competition between drainage and suction into the porous crust once the product is removed from the oil and begins to cool (Moreira, Sun, & Chen, 1997; Ufheil & Escher, 1996).

Crust permeability is therefore a critical parameter and has been considered as the main determining factor in oil uptake (Bouchon, Hollins, Pearson, Pyle, & Tobin, 2001; Pinthus, Weinberg, & Saguy, 1995). In fact, most of the pre-frying treatments oriented to reduce oil absorption are focused on altering crust permeability.

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Among them, we can find pre-frying treatments, such as hot-air drying and baking (Gamble & Rice 1987; Lamberg, Hallstrom, & Olsson, 1990) which, rather than merely reducing initial water content, as is usually believed, induce surface structural changes that limit the absorption (Moreno & Bouchon, 2008). The use of hydrocolloids with thermal gelling or thickening properties such as methylcellulose, hydroxypropyl methylcellulose, long fibre cellulose, corn zein and alginates, to reduce oil absorption, is also well documented (Albert & Mittal, 2002; García, Ferrero, Bertola, Martino, & Zaritzky, 2002). Their ability to reduce oil absorption is mainly based on their film-forming properties and crust-porosity reduction. The hydrocolloid mixture can be added to the product in several ways: (1) directly in the formula, such as in doughnuts and formulated products, (2) included in a batter or breading or (3) sprayed onto the product as a solution (Pinthus, Weinberg, & Saguy, 1993). In formulated products, the permeability of the outer layer of the product also depends on the thickness of the sheeted dough, which determines the structural resistance to water vapour escape. A stronger and more elastic network can result in a less permeable outer layer that may act as an effective barrier against oil absorption (Bouchon & Pyle, 2004).

Many formulated products are based on wheat flour (among other components). Wheat popularity is largely determined by the ability of wheat flour to be processed into different foods, which is mainly given by the unique properties of wheat-flour gluten proteins (Anjum, Khan, & Din, 2007). Products based on wheat flour dough are widely used in frying operations to produce products such as doughnuts, battered food and fritters, but they may also be sheeted and cut into small pieces to be fried. Wheat gluten's unique viscoelastic properties improve dough strength, mixing tolerance, and handling properties. Its film-forming ability provides gas retention and controlled expansion for improved volume, uniformity and texture, whereas its thermosetting properties contribute to structural rigidity and its water absorption capacity improves baked product yield, softness and shelf-life (Day, Augustin, Batey, & Wrigley, 2006). In relation to deep-fat frying, Fiszman, Salvador, and Sanz (2005), when frying battered squid rings, showed that the addition of gluten reduced oil absorption but, at the same time, it significantly increased moisture retention, resulting in a lower density and, consequently, a more porous and crunchier final batter texture. On the other hand, Rovedo, Singh, and Normen (1998) studied the effect of adding gluten to a potato starch-based dough and concluded that a higher gluten content caused an increase in oil uptake and a considerable expansion of the product. Gluten has also been used as an edible coating in fried products, due to its film-forming capacity and its barrier properties towards oil and water vapour (Albert and Mittal, 2002).

Another important constituent of wheat flour dough is water. To obtain suitable dough, the appropriate amount of water must be present. There is always competition among flour components for water, which makes water content a critical factor. Also, water is one of the most important constituents that determine the texture of fried foods. In the process of water vapourisation, the molecular volume of water increases rapidly as a result of the phase change from liquid to gas. When water vapour does not have a clear passage to the food/oil interface, this increase may lead to volume expansion of the fried food. In addition, volume expansion of water contributes to the porous structure of the crust and the rate of dehydration influences pore size distribution. Volume expansion also depends on the relative ease of migration of water through the surface matrix, which depends on the strength of the structure (Chen, Chang, & Hsieh, 2001).

From the previous discussion, it can be seen that the role of gluten and water in a dough matrix (to be fried) is of scientific interest. In fact, formulated sheeted products based on wheat flour could make it possible to investigate the effects of different product formulations on oil absorption, contributing to the understanding of the mechanisms that may be involved. Despite the interest, there is little research on this topic. Most of the articles that study the role of wheat flour constituents during frying are based on battered or breaded products, and the focus is centred on the structures formed by gluten and the impact of the batter on the quality parameters of the product (Fiszman et al., 2005; Hernando et al., 2007; Mohamed, Hamid, & Hamid, 1998). Accordingly, the main objective of this paper is to study the effects of gluten content, water content and dough thickness on oil uptake, and associated quality attributes, such as colour development and product expansion, during deep-fat frying. Experimental procedures are based on a formulated product made of a reconstituted blend of gluten and wheat starch instead of wheat flour, in order to accurately control ingredient proportions. The effect of a drying pretreatment on the different quality attributes of the fried product is also analysed.

2. Materials and methods

2.1. Materials

The product to be fried was a restructured matrix made of native wheat starch and vital wheat gluten (Asitec S.A., Chile), plus distilled water. The oil used was high oleic sunflower oil (Camilo Ferrón, Chile), which was kept constant for all experiments.

2.2. Sample preparation protocol

Samples were prepared ensuring two different water levels in the dough, 38 and 44% (w.b.). The amount of water added depended on the initial water content of the ingredients and was adjusted to ensure that all different products contained the specified amount. To do so, the exact water content of ingredients was determined experimentally by drying in a forced air oven at 105 °C for 24 h (to constant mass). For each of the two moisture content doughs, two dry mixture blends were prepared, containing either 8 or 12% gluten (% d.b.). In this way, only the dry ingredient proportion was modified.

The ingredients were mixed and sieved with a 40 mesh sieve (W.S.Tyler, USA). To form the dough, distilled water was added to the specific dry mixture blend, until it reached either 38 or 44% water content (w.b.). Half of the water was added at 15 °C while mixing for 1 min, using a 5K5SS mixer (KitchenAid, USA). After mixing for 2 min, the rest of the water was added. This water fraction was heated at 100 °C, and was also poured while mixing for 1 min. After mixing, the dough was sheeted using a LSB516 dough sheeter (Doyon, Canada) until reaching a final thickness of either 1 or 2 mm. The sheeted dough was then cut manually into 3.8 cm diameter discs.

Discs were either directly fried or fried after a predrying step. Drying was carried out under controlled conditions, using a Self-Cooking Center Model SCC661 (Rational, Germany), with dry air at 150 °C for 2 min. The drying time was kept constant in all formulations to study the effect of gluten moisture retention capacity during drying, and subsequently, during deep-fat frying.

2.3. Frying

Frying was carried out in an electrically heated fryer (model DF535T, Somela, Chile), which was thermostatically controlled to maintain the set frying temperature ±2 °C using an electrical control system ((PID + Fuzzy Logic, Veto, Chile). The fryer was filled with 4 l of oil, which were preheated for 2 h prior to frying and discarded after frying for 3 h. The frying temperature was set for all the experiments at 170 °C.

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