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Adhesion in fried battered nuggets: Performance of different hydrocolloids as predusts using three cooking procedures

A. Albert [a], I. Perez-Munuera [b], A. Quiles [b], A. Salvador [a], S.M. Fiszman [a,*], I. Hernando [b]

[a] Instituto de Agroquímica y Tecnología de Alimentos (CSIC), Apartado de correos 73, 46100 Burjassot, Valencia, Spain
[b] Departamento de Tecnología de Alimentos, Universidad Politécnica de Valencia, Apartado de Correos 22012, 46071 Valencia, Spain

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ABSTRACT

Batter systems have to turn into a crisp crust after frying and they have to adhere to food substrate surfaces which are sometimes very smooth. As a result, treating the substrate with a predust is highly recommended. Predust agents act by absorbing the moisture on the substrate surface, creating a rough outer surface on the substrate and ensuring optimal binding between substrate and batter. Normally, the same wheat flour used in the formulation of the batter is used for dusting. In this study, three different hydrocolloids were used as predusting materials for battered fish nuggets and their performances in three different cooking procedures were evaluated. Oxidised starch, xanthan gum and HPMC were compared with wheat flour (control), using deep frying, conventional oven and microwave oven. Image analysis, an innovative method in this area, was used to quantify adhesion. The performance of the hydrocolloids used as predusting agents depended on the cooking procedure.

1. Introduction

Convenience foods are in great demand due to social and cultural changes in recent years. One of the most important foods in this group is battered products.

Battered products such as fish nuggets are products which have been coated with batter and pre-fried, so the consumers or food service providers only have to apply a final cooking procedure, usually deep frying; however, the use of conventional or microwave ovens has been increasing lately and they are now among the most popular cooking procedures.

Batters are liquid mixtures consisting of water, flour, starch and seasonings into which food products are dipped prior to cooking. They act as barriers to moisture loss by protecting the moisture content, thereby ensuring a final product that is tender and juicy on the inside and at the same time crisp on the outside (Fiszman & Salvador, 2003). Modern industrial batters are coating systems which can be formulated to improve several functionalities, such as reducing oil uptake while controlling optimum moisture retention, to improve the cohesion and strength of the external layer, to favour adhesion to a variety of food surfaces or to create and retain crunchiness in the crust. In the last decade, quite a large number of studies of hydrocolloid performance in coating systems have been published (Akdeniz, Sahin, & Sumnu, 2006; Sahin, Sumnu, & Altunakar, 2005).

One of the key features which is common to all batters is assuring adhesion to the substrate throughout the elaboration and cooking processes. Creating coating systems that adhere to meat, fish or vegetable pieces is challenging for manufacturers (Brandt, 2002). Adhesion can be simply defined as the chemical and physical binding of a coating, both with itself and with the food product it coats (Suderman, 1983).

In engineering sciences, several well-established mechanical methods are used to quantify adhesion between two different surfaces. A few of the more common characterization methods include peeling tests, probe-tack tests, lap-shear tests, etc. Each of these experimental methods is focused on a particular level of adhesion or type of product. For example, peel tests, loop tack methods, and probe-type experiments are primarily used to quantify the adhesion of soft adhesives with varying degrees of adhesion in engineering materials (Crosby, 2003).

In the hydrocolloid field, these kind of mechanical tests were used to measure the ability of different hydrocolloid "glues" to adhere different surfaces in medical applications (Ben-Zion & Nussinovitch, 1997). In the present study, the surfaces involved consisted of preformed fish pieces and a fragile fried batter layer making almost impossible their handling for these mechanical methods. Traditionally, in batter systems the adhesion was related to yield (Baker, Darfler, & Vadehra, 1972; Corey, Gerdes, & Grodner, 1987; Hsia, Smith, & Steffe, 1992; Mukprasirt, Herlad, Boyle, & Rausch,

* Corresponding author. Tel.: +34 96 390 0022 16; fax: +34 96 363 6301 17.
E-mail address: sfiszman@iata.csic.es (S.M. Fiszman).

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2000;) in the sense that the more dough batter adhered the more final proportion of outer layer to total weight; that is, higher yield of the elaboration process.

Lack of adhesion at the interface is considered a severe fault of quality. Assisting adhesion, especially in the case of frozen substrates, predusts are commonly used. Predust is a fine, dry material that is dusted onto the moist surface of the food substrate before further coating is applied, If the batter is applied to a surface that is too moist it can slip, leaving some areas uncovered or covered with a diluted material that will then form too thin a layer. Predusting also helps to reduce any voids that may be caused by entrapment of air pockets between the substrate and the batter during batter application, preventing 'blow-off' and 'pillowing', and also tends to increase batter pick-up (Fiszman, 2008).

In a pioneering work, Baker et al. (1972) evaluated the predust material capacities of a series of ingredients from three large groups: starchy materials, proteins and gums. Since then, little research has been conducted in this area.

The most commonly used predust in industrial processes is wheat flour; in addition, certain modified starches are also used. By adding spices, predusts can act as flavour carriers as well (Van Beirendonck, 2003).

Hydrocolloids develop wet adhesive properties at various degrees of hydration, reaching maximum adhesion at an optimum degree of hydration (Chen & Cyr, 1970). Wetting is not a static process as water diffuses from the surface of the fish into the hydrocolloid layer and this makes the hydrocolloid particles to swell and interact with the batter. Spite of its gel forming properties and their ability to absorbing water HPMC is one of the cellulose derivatives less researched in the adhesion area; in the other hand xanthan gum and oxidised starch were linked to good stickiness properties (Fiszman & Salvador, 2003; Hsia et al., 1992).

The aim of this work was to evaluate HPMC, xanthan gum, and oxidised starch as predust materials. A method to quantify lack of adhesion of the outer layer after three different cooking methods for pre-fried, battered fish nuggets is proposed. The samples were cooked by deep frying, conventional oven and microwave oven, and the performances of the hydrocolloids were analysed. Other general quality factors of the final products were also measured.

2. Materials and methods

2.1. Food matrix

Frozen fish (hake) blocks were bought in a local market and stored in a freezer at −18 °C until used. The fish blocks were thawed at room temperature before processing and were cut with a sharp knife into rectangular-shaped portions ("fish nuggets") measuring 55 ± 1 mm, 35 ± 1 mm, and 20 ± 1 mm.

2.2. Sample preparation

A commercial batter formulation was used, consisting of wheat flour (85%), corn flour (5.8%), salt (5.5%), flavouring (0.6%) and leavening ($Na_2H_2P_2O_7/NaHCO_3$) (3.1%) (Adín, S.A., Paterna, Spain). The dry ingredients were pre-blended for 30 s at speed 2 in a Kenwood Major Classic mixer (Kenwood Ltd, UK) and mixed with water (1:1.2 solid to water ratio) for 2 min. Four different predustings were used, two starchy materials: 1) wheat flour (as control), 2) an oxidised starch (C^* BatterCrisp 05548, Cargill, Barcelona, Spain), a cellulose derivative: 3) hydroxypropylmethylcellulose (HPMC, Methocel E4 M, Dow Chemical Co., and a gum: 3) xanthan gum (Camp y Jové, Barcelona, Spain). The predusted fish nuggets were immersed in the batter dough. After being allowed to drip for 1 min, the battered food matrices were pre-deep-fried in sunflower oil at 190 °C for 30 s (Fritaurus Professional 3 domestic fryer, Barcelona, Spain), placed in plastic freezer bags (LDPE film, thickness 150 μ) and stored at −18 °C for two weeks. The samples were then cooked without thawing.

2.3. Cooking procedures

2.3.1. Deep frying (DF)

1 nugget at a time for 3 min at 180 °C in sunflower oil in a 3 l Fritaurus Professional 4 domestic fryer (Taurus, Barcelona, Spain).

2.3.2. Conventional oven (CO)

2 nuggets at time for 11 min at 225 °C in a domestic conventional oven (Fagor 2H 114, Mondragón, Spain).

2.3.3. Microwave oven (MO)

2 nuggets at time for 1 min 15 s in a domestic microwave oven (Samsung M1727, Barcelona, Spain) at maximum power, 800 W (measured power output 691 W according to International Standard IEC 60705), (IEC, 1988).

After cooking, all the samples were left to rest for 1 min before performing the measurements.

2.4. Adhesion

Cooked samples were cut in half transversally with a sharp knife and photographs were taken with an Olympus E-1500 camera (Center Valley, Pennsylvania, USA). Percentage of covering that remains adhered to the substrate (CRA) was calculated as:

$$\mathrm{CRA} = P/T \times 100$$

where P = pixels corresponding to the perimeter of the substrate where coating is adhered, and T = pixels corresponding to the total perimeter of the substrate.

High CRA values would indicate good adhesion properties in the final battered and cooked product.

The measurements were carried out with the help of Analysis AUTO software (Soft Imaging Systems GmbH, Münster, Germany). At least 15 cooked nuggets were measured for each sample.

2.5. Microscopy

Five nuggets (4–5 mm^3) of each sample were frozen with liquid CO_2 and cut with a cryotome (Shibuya Optical Co., LTD, Saitama, Japan). Photographs were taken with a Steoroscopic Zoom Microscope Nikon SMZ-1500 (Izasa, Barcelona, Spain) for better observation of the interface between the coating and the substrate.

2.6. Quality characteristics

In order to ascertain whether the different predusts affected the general quality of cooked nuggets a number of determinations were performed.

2.6.1. Batter pick-up

For each predust and cooking procedure (DF, CO and MO), four fish nugget were thawed, individually weighed, pre-dusted, immersed in the batter and cooked.

In batter-coated products, the term 'pick-up' is generally used to denote the amount of batter that adhered to the piece of food; the yield and the quality of the final product depend upon it. Therefore amount of batter adhering to a fish nugget was considered the batter pick-up value, calculated as:

$$\text{Batter pick-up}(\%) = (B/B+S) \times 100$$