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A film of alginate plus salt as an edible susceptor in microwaveable food

A. Albert, A. Salvador, S.M. Fiszman*

Instituto de Agroquímica y Tecnología de Alimentos (IATA-CSIC), Catedrático Agustín Escardino, 7, 46980 Paterna, Valencia, Spain

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ABSTRACT

An important quality problem when cooking or warming battered and breaded foods in a microwave oven is the resulting lack of crunchiness due the way microwaves heat foods. In this regard products are beginning to be designed specifically for microwave heating, by using active packaging (with susceptors) or/and by changing the batter formulation. In this study, a completely new approach was undertaken to avoid that problem: a film of alginate gel with high salt concentration between substrate and batter was used as an edible susceptor.

The performance of the proposed film was studied by Infrared Thermal Imaging (IRTI). A thermovision camera allowed to take thermographs after different heating periods in the microwave and to observe how heat was distributed once this new film of alginate plus salt was incorporated. The temperature histograms were also obtained from the thermographs to study the temperatures' distribution and their evolution with heating time. It could be observed that the alginate films produced more even heating patterns in the samples and shorter cooking times. In addition, the IRTI technique resulted to be a valuable tool to study the edible susceptor performance.

1. Introduction

Microwaving is a popular cooking procedure which has been extended quickly during last decades in all the developed countries due to its convenience. Microwave ovens utilized a technology that is completely different from other conventional and well-understood cooking procedures. Absorption of energy from the microwave field results in an internal heat generation within the product. There are certain food products that are more negatively affected by this particular heating pattern, such as crunchy products, namely, battered and breaded products. The microwaving of these kinds of products produces sogginess and dryness instead a crunchy crusts with juicy food cores. The main factors that impede a satisfactory heating of such products are, on the one hand, their own layered composition with different moisture contents, and on the other, the heating nature of the microwave ovens. These ovens heat foods from their inside, outwards. In addition, the necessary temperature (over water boiling point, 100 °C) to dehydrate the crust, hence making it crispy (their main quality characteristic), is not reached.

A large food service sector revolves around battered and breaded foods, mainly fast food restaurants. These would benefit from the possibility of having prefried breaded food in a freezer and using a microwave oven for the final cooking/heating when a customer asks for this product, saving time for both the restaurant and the customer. However, when a fried food with a crispy surface is warmed, the heating technology of microwave ovens makes the high-moisture interior areas reach higher temperatures. Consequently, the moisture is pumped to the surface, making the crust soggy (Datta, 2001).

The dielectric properties of a food material, along with its thermal and other physical properties, and the characteristics of the microwave electromagnetic field determine the absorption of microwave heating by the food (Nelson & Datta, 2001). The dielectric properties of usual interest are the dielectric constant ε' and the dielectric loss factor ε'', which are the real and imaginary parts, respectively, of the relative complex permittivity ε_r given by: $\varepsilon_r = \varepsilon' - j\,\varepsilon''$. The dielectric properties of food are critical to determine the rates and uniformity of heating and can be strongly influenced by its composition, particularly by its total water and salt content.

One effect of salt in frozen food is that it affects the freezing point by depressing it, leaving more water unfrozen at a given temperature. Salt also increases the ionic content and consequently the interaction with the microwave fields (Nelson & Datta, 2001).

There are a number of possible strategies to attempt to develop successful microwaveable battered and breaded products. One of them is to study the ingredients' intrinsic characteristics (e.g., structure, gelification capabilities) that can be used to avoid the migration of water from the interior to the surface of the crust.

* Corresponding author. Tel.: +34 963 90 0022.
E-mail address: sfiszman@iata.csic.es (S.M. Fiszman).

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Along these lines, different hydrocolloids have been used to improve the quality of breaded or battered products. Hydroxypropyl methylcellulose (HPMC) (Chen et al., 2008), dextrinized high-amylose flour (Lenchin & Harvey, 1985) and dextrins (Henning, 1995) has been used to increase crunchiness of battered during cooking by microwave. Another strategy is to evaluate the dielectric properties of foods. Although it is difficult to predict the dielectric properties of the different food items from its composition due to its complexity, the effect of salts has been demonstrated (Zhang, Lyng, & Brunton, 2007). In fact, according to the Hasted-Debye model salts depress the dielectric constant and increase the dielectric loss (Shukla & Anantheswaran, 2001). Finally, the third strategy is the use of susceptors, the last advance in packaging for microwavable foods. During cooking by microwave they create localized areas of high temperatures that may reach 200–260 °C and the food achieves crispness and a more effective browning (Albert, Varela, Salvador, & Fiszman, 2009; Varela, Salvador, & Fiszman, 2008; Zuckerman & Miltz, 1992).

As an alternative to metallic susceptors in packaging, food compositions containing high-boiling solvents and plasticizers, and ingredients with positive temperature coefficient of loss have been developed to induce the rapid rate of heating necessary, hence acting as edible susceptors. A number of patents related with these improvements for microwaveable foods can be found (Domingues, Atwell, Graf, & Feather, 1993; Hsu & Melachourius, 1993; Steinke, Josephson, Wampler, & Frick, 1990). However, these patents are all linked to the improvement in browning of microwaveable foods and, surprisingly, almost no systematic research has been conducted on their performance.

Most literature agrees in the fact that the key factor to a successful microwaveable product is the combination of an adjustment in its composition and the use of susceptors in the package to be heated. However, albeit the advances in food and packaging technology, no design of crispy battered/breaded food, that allows for an optimum microwaveable product has been achieved. Consequently, other cooking procedures, such as deep frying and conventional oven, are still mostly preferred.

The hypothesis for the present work was that an alginate gel containing all the salt of the formulation and formed by covering the food piece before battering and breading could act as a susceptor material for macrowaves. Alginate, a polyuronan consisting of beta mannuronic and guluronic acids, was selected as it dissolves in water to form viscous solutions and forms thermally irreversible firm gels in the presence of calcium. The guluronic acid residues preferently binds calcium ions and are responsible for gel formation by intermolecular crosslinking (egg-box model).

Infrared Thermal Imaging (IRTI) consists in recording the infrared radiation emitted from a body and creating colour-visible images of real-time maps of the distribution of this radiation (thermograms). The IRTI technique has many advantages since it is non-invasive, non-contact and non-destructive (Vadivambal & Jayas, 2011). The IRTI has been used in various fields as aerospace, agriculture, civil engineering, medicine and veterinary. In food technology it has been scarcely used, mainly in postharvest technology (Baranowski, Lipecki, Mazurek, & Walczak, 2008; Veraverbeke et al., 2006), to detect foreign bodies in food material (Ginesu, Giusto, Märgner, & Meinlschmidt, 2004; Meinlschmidt & Maergner, 2002; Warmann & Märgner, 2005), and to study the temperature distribution during or after cooking. Bakanowski and Zoller (1984) used the IRTI technique to study temperature distributions of cooked pork by microwave and conventional cooking methods. More recently, Manickavasagan, Jayas, and White (2006) have used it to study the heating pattern of barley, wheat and canola in a microwave dryer.

The aim of this work is to study the performance of a film made of sodium alginate as an edible susceptor in order to improve the quality of microwaveable chicken nuggets. In addition, the Infrared Thermal Imaging (IRTI) technique is assessed to study their heating pattern.

2. Material and methods

2.1. Samples

Four chicken nugget samples were prepared:

- Control nugget without alginate coating
- Sample A + S10: Nugget with an edible alginate coating set in a calcium chloride (3%) plus sodium chloride (10%) solution bath.
- Sample A + S20: nugget with an edible alginate coating set in a calcium chloride (3%) plus sodium chloride (20%) solution bath.
- Sample A + S30: nugget with an edible alginate coating set in a calcium chloride (3%) plus sodium chloride (30%) solution bath.

2.2. Nugget ingredients

2.2.1. Chicken substrate

Deboned chicken breast were bought in a local market and minced in a kitchen device (Thermomix TM 31, Wuppertal, Germany). The minced chicken breast was mixed with a commercial seasoning, specifically prepared without salt (Ceylan, Valencia, Spain).

2.2.2. Alginate

An alginate (Algogel 5540, Cargill, S.A, Martorell, Spain) solution (2% concentration) was prepared by mixing distilled water with the alginate in a high-speed stirrer (RZR1, Heidolph, Germany). The alginate concentration of this solution was selected after several preliminary trials to have an adequate viscosity for good nuggets' covering and handling. Powdered alginate was slowly poured into the upper part of a vortex created in the water by the stirrer.

The alginate layer was formed on the chicken substrate before the flour dusting step. All the sodium chloride of each formulation was in these alginate films (except the control).

2.2.3. Setting solution

A 3% calcium chloride (Panreac, S.A., Barcelona, Spain) solution was prepared by using distilled water; three different setting solutions were prepared containing 10, 20 and 30% sodium chloride (normal table salt) respectively. A 3% calcium concentration allowed the formation of a completely gelled thin alginate coating by diffusion (calcium acted as a crosslinking agent), without communicating unpleasant after tastes.

Several preliminary tests demonstrated that with a 30% of sodium chloride in the calcium setting bath, saturation was reached. Hence this concentration was selected as the maximum content of sodium chloride in the setting bath; two lower levels of sodium chloride concentrations were selected (10 and 20%).

2.2.4. Batter

The batter formulation (Adín, S.A., Paterna, Spain) consisted of wheat flour (90.80%), salt (5.50%, only in the control sample), monosodium glutamate (0.60%), sodium pyrophosphate (1.78%), and sodium bicarbonate (1.32%) as a leavening agent. The ingredients were pre-blended for 30 s at speed No.2 in a Kenwood Major Classic mixer (Kenwood Ltd, UK) and mixed with water (1:1.2; solid to water ratio).