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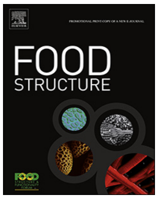

Characterisation of deep-fried batter and breaded coatings

K.Y. Voong*, A.B. Norton, T.B. Mills, I.T. Norton

School of Chemical Engineering, University of Birmingham, Edgbaston, B15 2TT, United Kingdom

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ABSTRACT

Deep-fried battered and breaded coatings provide foods with texture, flavour, reduced moisture loss and oil uptake. The physical characteristics of deep-fried batter and breadcrumb coatings was investigated for deep-fried prawns. Previous data on the effect of breadcrumb size on the microstructure of the coating is limited, therefore breadcrumbs were divided using the following sieve sizes and then applied to the coating in order to investigate the effect of breadcrumb size on the physical and mechanical properties: 4.0 mm, 2.8 mm, 2.0 mm, 1.4 mm, 1.0 mm, 710 µm, 500 µm, 355 µm. After frying, internal morphology was studied using X-ray microCT showing that the total porosity of coatings decreases with breadcrumb size whilst pore size distribution and structure thickness distribution increased with breadcrumb size. As crispness is a fundamental sensorial property of deep-fried battered products, crispness was evaluated by uniaxial compression to acquire mechanical and acoustical measurements simultaneously. Results showed decreasing breadcrumb size reduced the number of multiple failures, reduced jagged appearance of the force profile was observed, reduced maximum compression force and acoustic emission, which has been used as a representative of crispness. This study provides evidence of the importance of breadcrumb size in deep-fried battered and breaded formulations.

1. Introduction to batter coatings

The palatability of deep-fried foods is due in part to its unique flavour, taste and texture (Fiszman & Salvador, 2003). The high temperatures used for frying results in a desirable texture that is recognised as a dry and crisp crust contrasting a moist and tender core (Mellema, 2003). As well as enhancing the texture, a crusted coating prevents dehydration of the core, aids browning and reducing oil uptake into the core (Altunakar, Sahin, & Sumnu, 2004). Deep-fat frying is a simultaneous process of heat and mass transfer whereby water and other soluble materials are lost from the material being fried as oil penetrates the product (Mellema, 2003).

Batter is a flour and water mixture with additional salt, gums and seasonings, two main types are recognised; adhesion batters or tempura-type batters (Varela & Fiszman, 2011). Adhesion batters act as an interface layer between product and breadcrumb coating (Fiszman & Salvador, 2003), whereas tempuras are leavened chemically to create a puffed texture (Xue & Ngadi, 2007). Battered and breaded products have grown in popularity and are assessed on appearance, uniformity of coating, colour, crispness, adhesion and flavour (Loewe, 1993). As a textural attribute, crispness perception has been shown to be a combination of tactile and auditory components and depends on macroscopic and microscopic features within the food (Vickers, 1988).

1.1. Deep-fat frying process

Products are typically coated with a predusting layer to absorb excess moisture and provide additional adhesion for batter and breadcrumb layer (Mukprasirt, Herald, Boyle, & Rausch, 2000). Battered and breaded products are fully submerged into cooking oil and as surface temperature of the coating rises rapidly, surface moisture is evaporated off to allow surface drying and shrinkage (Mellema, 2003). The temperature of surrounding oil subsequently decreases but is compensated for by convection (Mellema, 2003). Other chemical changes that occur during crust formation include protein denaturation, non-enzymatic browning, caramelisation of sugars, glass transitions, oxidation and starch gelatinisation (Altunakar et al., 2004). Development of a positive pressure gradient within the fried product causes moisture to be released as vapour via cracks, open capillaries or explosive evaporation, thus creating voids and entry points for oil to penetrate (Mellema, 2003). As vapour creates voids for oil penetration, it is suggested that oil uptake is largely determined by moisture content (Mellema, 2003). In fact, it has been shown that food with high moisture loss result in higher oil uptake (Gamble, Rice, & Selman, 1987). Therefore, moisture and oil content have a large influence on crisp texture. Studies focusing on the relationship between crispness and high moisture products are limited and measurement procedures are different depending on product type (Antonova, Mallikarjunan, & Duncan, 2003).

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* Corresponding author.
E-mail address: axv502@student.bham.ac.uk (K.Y. Voong).

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Oil that penetrates the voids act as both as a heat transfer mechanism and a final ingredient, with reports of up to 1/3 of the total products weight being oil (Mellema, 2003). High levels of oil ensure structural integrity of batter is maintained by preventing shrinkage and collapse, providing satiety but also posing as a health risk. Numerous studies have suggested that oil absorption occurs predominantly during post-frying cooling (Aguilera, Stanley, & Baker, 2000; Moreira, Sun, & Chen, 1997; Moreno & Bouchon, 2013).

1.2. Crispness perception

'Wet' crisp such as apples, contain fluid within their cells balanced by intracellular forces from strength and elasticity of the cell wall, thus creating turgidity (Vickers & Bourne, 1976). Rupture of these cell walls produces a sound pressure wave that is responsible for the perception of crispness (Vickers & Bourne, 1976). 'Dry' crisp such as potato chips have brittle cell walls with air-filled cavities (Duizer, 2001). A continuous force exceeding a threshold will bend and break this brittle material, fragments will bend back to their original shape, thus setting of vibrations and sound pressure wave (Vickers & Bourne, 1976). Deep-fried battered and breaded products have properties of both wet and dry crisp, in that they are cellular structures that contain both air and liquid oil.

A combination of acoustic and force deformation measurements can be used as an indication for oral crispness (Chen, Karlsson, & Povey, 2005; Duizer, 2001; Taniwaki & Kohyama, 2012). Humans perceive sound of cellular structure breakage via air conduction to the ear and bone conduction through the tongue, cheeks and mandible to the ear (Duizer, 2001). As low frequencies are absorbed by muscle tissue during bone conduction, the recordings of crispness are louder than sound perceived during mastication (De Belie, Harker, & De Baerdemaeker, 2002). When force is applied to a material, the stored strained energy is converted to acoustic energy, individual molecules in the air are displacing others causing a vibration and thus a sound wave is propagated.

1.3. Breadcrumb coating

Breadcrumb coating derives from baked bread that is dried and comminuted to form smaller sizes (Pickford, 2003). Breadcrumbs often consists of a mixture of sizes to create a non-uniform layer.

As battered and breaded products will have differences in morphology and composition between the layers, this study aims to characterise the physical properties of a battered and breaded coating only. Information on the effect of breadcrumb size is limited, this study aims to characterise the physical properties of breadcrumb coatings of different crumb size. Properties investigated included total porosity, pore size distribution, compression force and acoustic emission as indicators of crispness.

2. Materials & method

Standard samples consist of white prawns (spec 50–60, Hyperama Plc, UK) butterflied and deveined, then coated with predust flour, batter and then breadcrumb coating. To investigate the effect of breadcrumb size, breadcrumbs were separated using the following sieve apertures: 4.0 mm, 2.8 mm, 2.0 mm, 1.4 mm, 1.0 mm, 710 µm, 500 µm, 355 µm (Endecotts Ltd. London, England). Each size as an outer coating was investigated post-fry. All samples were fried in at 195 °C for 42 s in soya bean oil (Fryer model NPDF3, Parry Catering Ltd UK).

2.1. Coating pick-up

The amount of coating adhering to the sample prior to frying was calculated by the weight of coated sample divided by weight of sample before coating multiplied by 100. Pick-up percentage was calculated for each coating step (predust, batter, breadcrumb). To avoid batter dripping from the sample effecting the measurement of pick up, samples were allowed to drip for 30 s before weighing.

2.2. Moisture and oil content

Moisture and oil content were calculated for the coating post-fried to assess changes in moisture and oil content with breadcrumb size. Moisture content was determined by difference in weight after vacuum oven-drying for 24 h at 70 °C. Oil content was determined by Soxhlet solvent extraction for 5–6 h, followed by rotary evaporation. Samples were carried out in three replicates.

2.3. Confocal microscopy

Batter and breadcrumb coating cross-sections were stained after frying with Nile red (Sigma Aldrich 72485, UK) (0.01%) to observe the depth of oil penetration. A confocal microscope (Leica TCS SP5, Germany) was used to acquire images after exciting at 543 nm with a He/Ne laser. Image acquisition was performed at a pinhole size of 100 µm with 10 × magnification objective lens.

2.4. X-ray micro computed tomography (MicroCT)

Samples were scanned using a voltage of 59 kV, current of 100 µA and no filter (Skyscan 1172, Bruker, Belgium). Samples were covered in parafilm to prevent moisture lost. NRecon, CTAn and CTVox was used to reconstruct images and carry out 3D analysis. Experiments were carried out in three replicates.

2.5. Texture and sound emission analysis

Compression testing was carried out using a TA XT plus Texture Analyser (Stable Micro Systems Ltd. UK) with 5 kg load cell, 3 g trigger force, P/40 cylindrical aluminum probe at a constant speed of 0.5 mm/s. Deep-fried battered and breaded coating were peeled from the substrate, cut into 20 mm diameter shapes and subjected to 60% compression ratio with top surface of the coating facing upwards.

Acoustic envelope detector (AED) (TA-XT Plus, Stable Micro Systems Ltd., UK) was used for force-displacement acoustic measurements and recorded using Texture Exponent. A microphone (12 mm diameter) was positioned 7 cm horizontally from center of platform. Calibration was carried out using a sound calibrator at 94 dB and 114 dB at 1000 Hz. Any background noise was filtered using 3.125 kHz corner frequency. A gain of AED was set at 3 with data acquisition rate set to 500 points per second for force and sound measurements. Ten replications were performed for each sample. Parameters extracted included: Maximum force, area under force curve, force peaks (drops in force above 0.049N), maximum sound pressure level and number of sound peaks (drop in sound pressure level above 10 dB).

2.6. Statistical analysis

One-way ANOVA and post-hoc Tukey test was performed to evaluate any differences between samples.

3. Results and discussion

3.1. Microstructure of fried batter and breadcrumb coatings

The microstructure of batter coatings has been previously explored with microscopy techniques (Llorca, Hernando, Pérez-Munuera, Fiszman, & Lluch, 2001; Moreno & Bouchon, 2013). The use of microscopy to study internal morphology of deep-fat fried batter is demonstrated in Fig. 1, which shows a decrease in fluorescence deeper within the coating, highlighting differences in structure throughout the