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Insights into the texture of extruded cereals: Structure and acoustic properties

Hélène Chanvrier [a,*], Ewa Jakubczyk [b], Ewa Gondek [b], Jean-Claude Gumy [a]

[a] NESTEC S.A., Nestlé PTC Orbe, Route de Chavornay 3, 1350 Orbe, Switzerland
[b] Department of Food Engineering and Process Management, Warsaw University of Life Sciences, Nowoursynowska Str. 159C, 02787 Warsaw, Poland

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ABSTRACT

Structure and texture of extruded cereals were investigated on products obtained from different flours (whole wheat flour and corn flour recipes) and for different fibre addition levels. Texture, i.e. mechanical properties, was assessed through a compression test and structure was analysed via microcomputed X-ray tomography and 3D image analysis. The addition of fibres at different levels in wheat and corn recipes strongly decreased porosity, thus leading to harder products. The acoustic properties, obtained from a contact method assumed to simulate biting and bone conduction of the sound, are also modified by the amount of added fibres. The acoustic properties can be related to product structure and mechanical properties.

Industrial relevance:

- This study was performed within the European InsideFood project and extruded cereals were produced in an industrial environment.
- The main objective was to find the drivers of texture changes in extruded cereals when fibres were added in the recipe.
- Texture measurements, i.e. mechanical properties of cereals assessed by compression tests are commonly used as physical measurements.
- Even though acoustic emission has largely been used before in previous studies, the method used here differs as it is a contact method.
- The uniqueness of this study was to combine structural information with physical results (hardness and acoustic emission), and to find out the main structure attributes that drive these physical attributes.
- Understanding the impact of structure on texture is key, since it helps in designing the right structure through the right processing conditions to target the desired texture properties.
- This study showed that cellular structure is key – however, another level that has also to be addressed is the wall structure – at the moment, we are still lacking convenient and quick methods to assess dispersion of protein, and fibres in the starch matrix (microscopy is time-consuming). It is known that it plays a role in the breaking behaviour of cereal products. We have seen here in our study that acoustic emission can be linked to the number of peak upon compression. This may reflect the structural organisation at the walls level.

1. Introduction

Amongst organoleptic properties of low moisture extruded cereal products, crispness is one of the main attributes generating consumer pleasure during consumption. Definition of crispness may vary from one study to another. In earliest studies, authors only took into account the mechanical force needed to break a product into pieces (Barret, Cardello, Lesher, & Taub, 1994), whereas, later on, other studies considered the combination of the noise created when biting as well as the fracture or breakdown perception (Dacremont, 1995; Duizer, 2001). In the end, crispness results from many breakages during mastication of dry products, which induce noise creation. It is now acknowledged that mechanical and acoustic analyses are appropriate in order to characterize texture of cereals at low moisture level (Chaunier, Courcoux, Della Valle, & Lourdin, 2005). The acoustic signal gives a lot of information on fracturing process and material behaviour. The acoustic parameters can be related to sensory perceptions of crispness (Luyten & van Vliet, 2006). The combination of acoustic emission detection and force–displacement measurement can reveal more information about crispness than any technique alone (Chen, Karlsson, & Povey, 2005; Saeleaw & Schleining, 2011).

Acoustic emission (AE) is a phenomenon of generation of elastic waves within a material as a result of internal disintegration caused by mechanical loading. The deformed material can be a source of acoustic emission signals that propagate across the material to the sensor. This

* Corresponding author. Tel: +41 24 442 71 11; fax:. +41 24 442 74 44.
E-mail address: chanvrier@rdor.nestle.com (H. Chanvrier).

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acoustic signal contains information about the microstructure and texture properties of the product. Traditionally, acoustic measurement of food can be done during crushing of products and recording of sound with the application of a microphone (Lewicki, Marzec, & Ranachowski, 2009). In recent years, contact methods of acoustic emission measurement have been applied for texture evaluation of extruded bread (Gondek et al., 2013; Marzec, Lewicki, & Ranachowski, 2007), breakfast cereals (Gondek, Lewicki, & Ranachowski, 2006), apples (Zdunek, Konopacka, & Jesionkowska, 2010) and sugar gels (Herremans et al., 2013). The contact acoustic emission method enables recording vibrations of material during deformation using the sensor in mechanical contact with a sample. The mechanism of generation and propagation of elastic waves during contact acoustic emission test is similar to the vibration mode of sound propagation during eating (Zdunek et al., 2010).

Previous studies also considered the use as X-ray microtomography for the structure analysis of porous cereal products such as bread or extruded cereals (Babin et al., 2006; Falcone et al., 2004; Falcone et al., 2006). Regarding the relationships between porous structure of extruded starchy products and their mechanical properties, Babin, Della Valle, Dendievel, Lourdin, and Salvo (2007) showed that for the same relative density, lower mechanical resistance was obtained for products displaying a wide range of cell size and wall thickness. If relative density is key for mechanical resistance, as explained by Gibson–Ashby relationship, the internal structure of porous extruded cereals has also an impact. The objective of the present work was to gain insight on the texture of extruded cereals, that is to say, to understand the impact of structure on their physical properties such as mechanical and acoustic properties. The relationships, as described in Fig. 1, are studied in the purpose of designing the right structure through the right processing conditions to reach the targeted food product properties. When products are improved nutritionally by adding fibres for example, this approach can be undertaken in order to obtain the targeted texture. Food product structure, studied at different length scales, is key to understanding the link between processing conditions and final product properties. In our study, the focus was on the cellular structure of the porous extrudates assessed by X-ray tomography and 3D image analysis. The acoustic properties were measured with a contact method, which is a new solution for testing food simulating process of biting and bone conduction of the sound (Lewicki et al., 2009). In the frame of the study, a variety of extruded cereals was produced by modulating structure by different means; either by changing flours in the recipe (whole wheat flour or corn) and/or by adding fibres. The texture assessed by combination of mechanical and acoustic methods was globally discussed with regard to the structure data.

2. Material and methods

2.1. Composition of extruded cereals

Two recipes were extruded with a BC21 cooking-extruder (Clextral, Firminy, France): wheat and corn recipes were supplemented in fibres (wheat bran or oat bran). The extrusion-cooking was performed at 20% moisture and 135 °C. Wheat recipes were composed of 40, 60 and 80% wholegrain wheat flour and fibres were added at two levels: 10 and 20%. For corn recipes (also containing 34% of soya flour), fibres were added at 14, 26 and 32% (Table 1). After extrusion, products were dried down to 3% moisture content in average. The detailed recipes and processing conditions are fully described by Chanvrier et al. (2013).

2.2. Texture assessment by compression test

Mechanical properties of extruded cereals were investigated by compression test using a Kramer shear cell equipped with a 5000 N load cell on a TA HD plus Texture Analyser (Stable Micro Systems, Surrey, UK). The displacement speed was set at 1 mm/s and the thickness of the cereal bed was 17 mm. The maximal compression force (N) and number of force peaks (with drop in force higher than 100 g) were extracted from the force versus displacement curve. Average maximal force and number of peaks were calculated from triplicates. The average coefficient of variation was 3.2%.

2.3. Acoustic measurements

Between the head of the TA HD plus Texture Analyser (Stable Micro Systems, Surrey, UK) and the deformation tip, a piezoelectric accelerometer 4507B (Brüel & Kjær, Naerum, Denmark) was installed in a specially-designed adapter to measure vibrations emitted by the compressed material in a Kramer shear cell. An integral amplifier and acoustic background filters enabled us to measure the sound emitted by the analysed product in a frequency range of 0.1–18 kHz. The acoustic emission signal was recorded in a contact way at a sampling frequency of 44.1 kHz using analogue-digital processing card type 9112 by ADLINK Technology Inc. and analysed according to procedure described by Gondek et al. (2013). The selected acoustic descriptors defined by Gondek et al. (2006): number of acoustic events, average energy of single event and total acoustic emission energy (arbitrary unit, a.u.) were determined at a discrimination level of 1000 mV. Analyses were carried out in 5 replications.

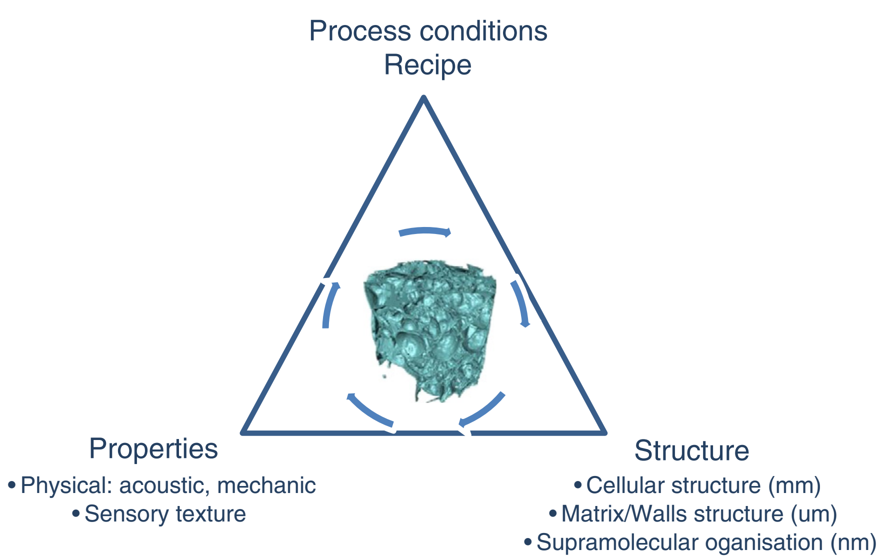

Fig. 1. Approach used to gain insight into the texture of extruded cereals: building the relationships between process–structure-properties.