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Ultrasonic Evaluation of Static and Dynamic Properties of Noodle Dough for Industrial Applications

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1. Introduction

Characterisation of the mechanical properties of soft food materials is crucial in the food industry, both for process design and for quality enhancement purposes. Sheeting is a common process in food processing and consists of passing dough through a gap between a pair of rotating rolls. In the case of the Asian noodle industry, composition and work input during the sheeting process are important parameters that influence the mechanical properties of dough, and as a consequence, the final product quality. Quality control is an essential step in industrial food processing. Ultrasound is a very convenient tool to assess these properties via sound velocity and attenuation [1, 2]. In general, the measurements are performed at the end of processing with dough placed between two plastic plates. In the case of food products, a non-contact technique is important to avoid damage or contamination of the food. An accurate and fast determination of the mechanical properties in citu will certainly improve the industrial food processing, allowing the manufacturers a better control of the uniformity of their product during production.

To address this need, we are conducting a detailed study of noodle dough with air-coupled ultrasonic techniques in a frequency range from 200 kHz to 400 kHz. Such study allows the characterization of the mechanical properties of the noodle dough, and an assessment of how these properties are affected by composition, processing conditions and bubbles entrapped in the dough matrix during sheeting. This study brings a better understanding of these material properties, which are being used to develop an ultrasonic air-coupled technique for real-time on-line quality control during noodle dough production.

2. Materials and Methods

There are three components that constitute noodle dough: flour, water and salt. Flour made from Canada Western Red Spring (CWRS) was selected based on its suitability for noodle production.

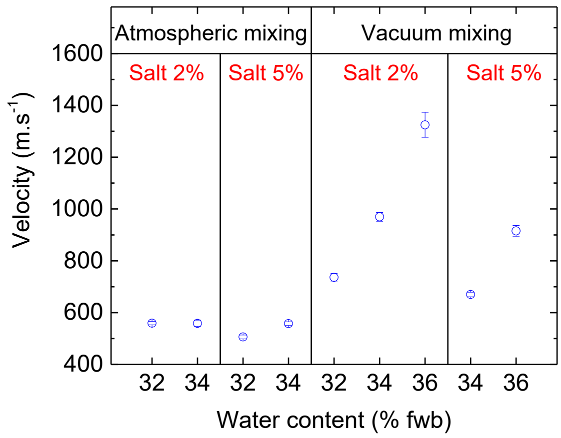

Fig. 1 Velocity measured at 200 kHz for different noodle dough compositions and processing conditions.

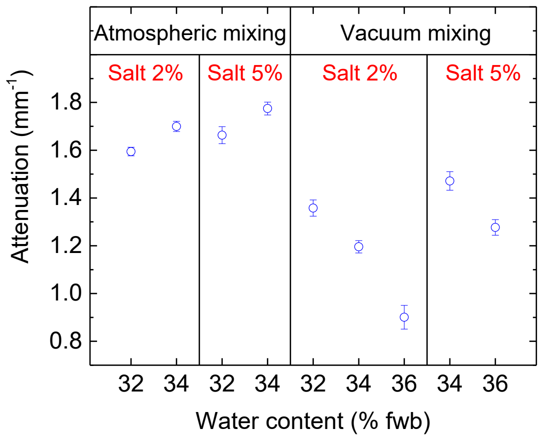

Fig. 2 Attenuation measured at 200 kHz for different noodle dough compositions and processing conditions.

In order to evaluate the sensitivity of ultrasound we varied dough composition by changing NaCl concentration (from 1% to 5% of the flour weight) and water quantity (from 32% to 36% of the flour weight). We also controlled the number of lamination steps performed before the elongations (work input) and the mixing conditions (under atmospheric or reduced pressures).

The ingredients (as described above) were mixed into dough crumbs using an Ohtake vertical mixer by mixing at 100 rpm either at atmospheric pressure or under partial vacuum (p = 0.25 atm) for 10 min. The dough crumbs were laminated into a dough sheet by passing through a roll gap setting of 3.5 mm followed by 30 min of resting with the dough enclosed in a plastic bag. The dough was then sheeted in four continuous and successive reduction passes (2.5 mm, 1.8 mm, 1.3 mm and 1.0 mm) on a pilot scale noodle sheeting stand (Ohtake Noodle Maching Mfg. Co. Ltd, Tokyo, Japan).

Acoustic measurements were performed in transmission mode using NCG200-D25 piezoelectric transducers made by the UltranGroup (State College, PA, United-States) with a central frequency of 200 kHz. In order to take advantage of the full bandwidth of these transducers, a pulser (Model 5058PR from Panametrics) was used as a generator. The signal was then recorded on a computer equipped with a PCI oscilloscope card (Octopus 8227 from GaGe).

Experiments were performed in a laboratory with controlled conditions and in a pilot-plant environment on an industrial sheeting machine during the production of noodles at the Canadian International Grains Institute (CIGI, Canada).

The propagation through the dough is characterized by its complex wavenumber k, depending on the angular frequency ω, the phase velocity v and the attenuation α:

$$k = \omega/v + i\,\alpha/2.$$

Because of huge differences between the acoustic impedances of the noodle $Z_{\text{noodle}} \approx 10^6$ Rayl and the impedance of the air $Z_{\text{air}} \approx 443$ Rayl, almost 99.9% of signal energy is reflected, very little energy goes inside the dough and so the reflection must be taken into account for velocity and attenuation calculations using an iterative process as developed in [3].

3. Results

Figure 1 and **Figure 2** show that all the composition and processing parameters of the noodle dough sheets studied have an influence on both attenuation and velocity. Another observation is that a higher value of the velocity is associated with a smaller value of the attenuation.

The quantity of salt has a clear influence on the acoustic properties of the dough which can be explained by its impact on the number of bonds between the different proteins constituting the gluten network, the mixing under vacuum leads to a more homogenous dough structure, the quantity of water changes the final texture of the dough, and the amount of work input needed to obtain the dough sheets also affects the dough texture. The gluten network being the main structural component of the dough, all these modifications affect its mechanical properties and consequently modify the propagation of acoustic waves.

The mixing at reduced pressure leads to a more uniform hydration of the flour, resulting in a continuous network of gluten instead of a thread-like network found in the dough mixed under atmospheric pressure. Water is more evenly incorporated in dough mixed under vacuum, so the quantities of water in the mix for the doughs mixed under vacuum are higher.

Vacuum mixing helps the development of gluten during the sheeting and improves the quality of the texture of the final product. For the ultrasonic results, there are clear differences between the two mixing conditions - the doughs mixed at atmospheric pressure have smallest value of velocities and larger values of attenuation than the dough mixed under a reduced pressure.

The influence of the water content is clearly shown for the doughs mixed under vacuum, but we do not see such a clear effect for the ambient mixed doughs.

4. Conclusions

In this work, an ultrasonic technique was developed to perform measurement of the mechanical properties of noodle doughs without contact. This technique was first applied in a laboratory context to assess the feasibility of the measurements and was then applied during the production of the dough. We were able to measure the mechanical properties of the noodle doughs and differentiate them depending on composition and/or processing conditions. The non-contact ultrasonic technique can be used as a quality control during the production by comparing the mechanical properties of the doughs on production with expected values.

Acknowledgment
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