Chewing Mechanisms Investigated Using Finite Element Modeling (FEM) for Two Soft Cereal Foods

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Abstract

Cereal foods can be considered as cellular solids: texture is defined by their structure and mechanical properties [1]. Elderly people show a significant alteration of oral health [2] and salivation [3], causing difficulties to eat. Therefore, there is a need to understand chewing mechanisms of soft cereal foods in order to develop better food products that are fit for this population. In this context, our aim is to understand and predict the mechanical and microstructural changes of two ductile cereal food foams under conditions that mimic oral processing (compressive loading). In this purpose, sponge-cake (SC) and brioche (B) were selected, and their mechanical properties characterized under large compression levels (>90% in height reduction). Two distinct non-linear mechanical behaviors were observed: B showed plastic deformation and SC displayed hyper-elastic behavior. The apparent Young's modulus was higher for B (10kPa) than SC (5kPa). By using COMSOL Multiphysics® and the Structural Mechanics Module, 3D models of the intrinsic cell wall material and a unit cell were built using primitive shapes. Finite element computation was then used to derive the mechanical model representing the compressive response up to densification as compared to experimental data. Thanks to the development of a secant approach, the densification is modeled as a local increase in stiffness and implemented using an exponential function of the applied load[4].The mechanical response of both foods was accurately represented. Additionally, the evolution of the cellular structure of the two foods under compression was captured using high resolution ultra-fast x-ray microtomography at the European Synchrotron Radiation Facility (ESRF). The compression response of the samples was recorded in situ at all stages. The resulting 3D images will provide useful information in order to better capture the evolving cell contacts and improve the current models developed using COMSOL Multiphysics®.
These results are a first step towards a more accurate description of the mechanical and structural changes that occur during chewing in cereal soft foods and open prospect to reverse-engineering of foods with a desired mechanical response to compressive loading.
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