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Mechanical characterization of kernel and shell of hazelnuts: Proposal of an experimental procedure

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ABSTRACT

In order to improve the performance of selecting machines for non-conform and damaged hazelnuts and to enhance the numerical modelling of anisotropic behaviour of hazelnuts, the mechanical properties of shells and kernels are useful experimental data. A procedure to experimentally obtain physical and mechanical properties of hazelnuts is described and the optimized specimen shapes to obtain stress to failure and elastic modulus values for kernel and shell are also defined. The procedure is applied to a commercial variety of Italian hazelnuts and the mechanical properties are experimentally obtained both for kernel and shell on specimens made from conform and damaged hazelnuts.

1. Introduction

To obtain quality hazelnut kernels, three main processing phases are necessary: selection after harvesting, shelling and removal of hidden non-conformities. The traditional harvesting method consists in collecting hazelnuts from ground and a preliminary accurate selection is then needed to avoid stones, ground, brunches, leaves, etc. Hazelnuts are subjected to quality loss during the shelling process and physical characteristics such as shape, size, thickness and shell texture are the main factors affecting the kernel extraction (Saklar et al., 1999; Guner et al., 2003; Koyuncu et al., 2004; Valentini et al., 2006; Ghirardello et al., 2009). The shelling process is widely investigated in literature and the performance of a shelling machine is commonly evaluated in term of undamaged and damaged ratios, left-in-the-shell kernels, cracked nuts and unbroken nuts (Ozdemir and Ozilgen, 1997, 1999). After shelling and removal of non-conform kernels, the last operation is the roasting process whose main parameters are: air temperature, oven air velocity and roasting time (Saklar et al., 2001, 2003; Demir and Cronin, 2005; Simsek, 2007; Alamprese et al., 2009).

The quality requirements of hazelnuts are evaluated according to their chemical and nutritional properties, but the quality of hazelnut kernels relies also on their appearance, i.e. a clear and uniform colouring. However, this parameter is not completely adequate to identify a full-quality kernel because an inner darker coloured oily appearance reveals hidden damages, which cause many discards. Other types of defects, which need selection and removal, are rotten kernels and/or hit by bed-bug kernels.

The experimental characterization of shells and kernels is a challenging topic to improve the quality of the final product. Many literature papers describe procedures to find the mechanical properties of raw and roasted kernels (Braga et al., 1999; Aydin, 2002; Ozdemir and Akinci, 2004; Demir and Cronin, 2004; Ghirardello et al., 2009) and the experimental testing on hazelnuts generally relies on compressive testing of kernel and shell by means of universal testing machines. Compressive force-crosshead displacement curves are widely used to measure textural properties in food products (Guner et al., 2003; Carcel et al., 2012): initial slope, maximum force, energy until failure and other curve-related parameters have been described and correlated with textural parameters of hazelnuts. In literature, the fracture load value on the force–deformation curve is named as maximum force, peak force, or first peak of break (Saklar et al., 1999). Like for kernels, experimental tests are performed on whole hazelnuts to obtain the structural properties of the shell but without obtaining information on the material behaviour. For example, the shell is made by a wood behaving material with fibres set along the principal stress directions and a compressive test on the whole shell does not allow to discriminate the contribution of the fibres in each direction. In a test campaign (Demir and Cronin, 2004), a small rectangular prismatic specimen, including the inner cavity present in the core of each hazelnut, was cut from the whole kernel to simplify the calculation of stress and elastic modulus when a compressive axial force loads the specimen section. Again the specimen geometry affected the results and it did not allow obtaining material properties.

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In the present paper, specimens of shell and kernel are investigated in order to define an experimental procedure to obtain the mechanical properties of the shell and kernel materials. Aim of the proposed experimental testing procedure is to improve the discrimination between conform and non-conform hazelnuts. An additional fall out of the procedure consists in obtaining reliable constitutive models for a proper numerical modelling of both shell and kernel mechanical behaviour (i.e. simulations of falling, shocks, fluid-dynamic effects, etc.). The proposed experimental procedure is validated by means of testing on conform and non-conform lots of a commercial variety of Italian hazelnuts and the experimental results are analysed and discussed.

2. Materials and methods

Hazelnuts from Italian quality Tonda Gentile Bilobata were used for all the experimental tests presented in the study. The crop was collected during 2010. According to Saklar et al., 2003, ripeness is the principal factor that affects the physical and mechanical properties of hazelnuts. In the present paper, hazelnuts, aged one year from harvest, were tested.

Samples have been obtained from conform, non-conform and roasted kernels. The roasting conditions are 120 °C for 40 min. The following groups of hazelnuts have been considered:

- Group 1, raw conform kernels and shells.
- Group 2, raw rotten kernels.
- Group 3, raw and hit by bed-bug kernels.
- Group 4, roasted kernels.

Three kinds of tests have been performed:

- Compressive test on whole hazelnuts to obtain the stiffness and the corresponding anisotropic properties of the hazelnut.
- Compressive test on kernel specimens to obtain the ultimate (rupture) compressive stress (*UCS*) and the elastic modulus (E_k) along the principal directions and the corresponding anisotropic properties of the kernel.
- Bending tests on shell specimens to obtain the ultimate (rupture) bending stress (*UBS*) and the elastic modulus (E_s) along the principal directions and the corresponding anisotropic properties of the shell.

The specimen shapes of kernel and shell have been defined and obtained by means of different procedures according to the corresponding experimental tests. In the following paragraphs the procedures for obtaining specimens and for testing them, along with data processing procedures, are described. Results processing allows obtaining the mechanical properties of hazelnut, kernel and shell.

2.1. Samples

Hazelnut shell and kernel show nearly a symmetric shape, which can be described by means of three main dimensions along three perpendicular directions (Guner et al., 2003; Koyuncu et al., 2004; Valentini et al., 2006). These dimensions are shown in Fig. 1: length *A*, width *B* and thickness *C*.

Three kinds of specimens have been tested in the present research work.

To investigate the mechanical properties of the whole shell, tests were performed on the whole shells of conform hazelnuts, compressed along the three main directions *A*, *B* and *C*.

The second kind of specimens has been used for kernel characterization. The specimen shape is cylindrical, 5 mm high and 5 mm diameter, and it is obtained by means of two dedicated tools shown in Fig. 2: the first tool cuts a slice (thickness of 5 mm) from the kernel with two parallel surfaces, the second tool presents a hole of 5 mm diameter and it derives a cylinder from the kernel slice. Cylinders were cut with symmetry axes parallel to the three main directions *A*, *B*, *C*. The kernel specimens were obtained from each of the four described groups of hazelnuts, basing on their kernel conformity.

The third kind of specimens has been defined to investigate the material properties of the shell along the three main directions *A*, *B*

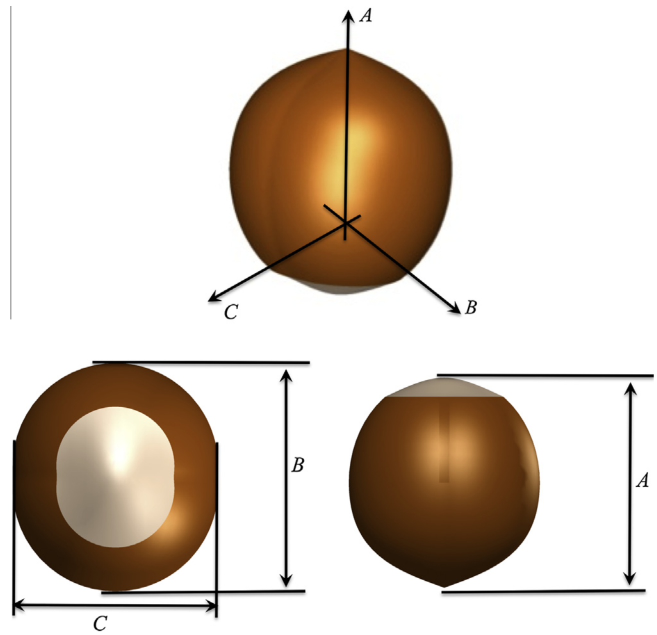

Fig. 1. Reference measuring system defined along hazelnut shell and kernel and example of compression of them along *A*, *B* and *C* directions.

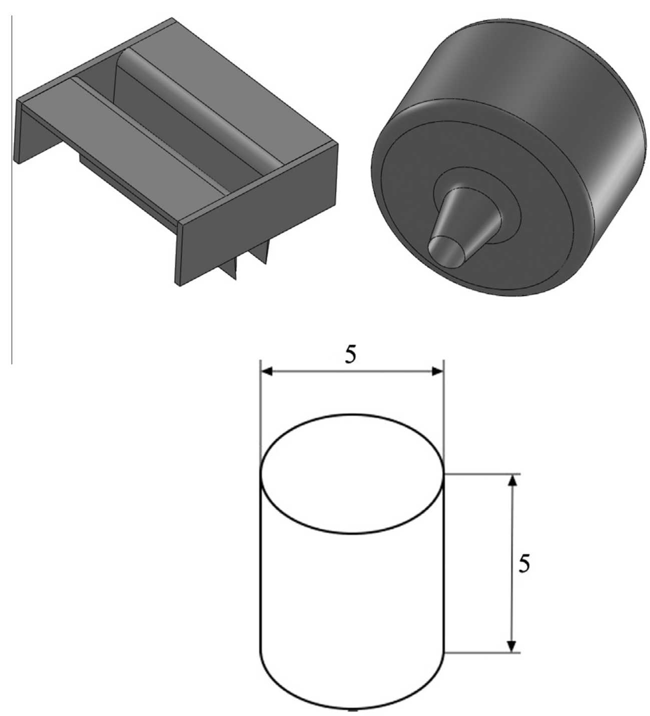

Fig. 2. Tools for extracting the kernel specimens; dimensions in mm.