Available online at www.sciencedirect.com
SCIENCE DIRECT®

Postharvest Biology and Technology 37 (2005) 163–173

Postharvest Biology and Technology

www.elsevier.com/locate/postharvbio

Micromechanical behaviour of onion epidermal tissue

E. Vanstreels [a,*], M.C. Alamar [a], B.E. Verlinden [a], A. Enninghorst [c], J.K.A. Loodts [b], E. Tijskens [b], H. Ramon [b], B.M. Nicolaï [a]

[a] *Flanders Centre/Laboratory of Postharvest Technology, K.U. Leuven, W. De Croylaan 42, B-3001 Heverlee, Belgium*
[b] *Laboratory for Agricultural Machinery and Processing, K.U. Leuven, Kasteelpark Arenberg 20, B-3001 Heverlee, Belgium*
[c] *Institut für Obstbau und Gemüsebau der Rheinischen Friedrich-Wilhems-Universität, Auf dem Hügel 6, D-53121 Bonn, Germany*

Received 18 November 2004; accepted 4 April 2005

Abstract

Onion epidermal peels were used as a model system to study the micromechanical behaviour of plant tissue in relationship to the structural parameters of the cells in the tissue. Mechanical properties of onion epidermal tissue were measured using a miniature tensile stage mounted under a microscope. Epidermis peels were subjected to tensile tests in longitudinal and transverse direction, while the deformation of the individual cells in the tissue was monitored. Onion epidermal peels were found to produce in both directions a biphasic stress–strain curve consisting of two clearly distinguishable linear parts of different slope with a transition zone in between. Cell area was found to exert a significant negative influence on stiffness and strength of the samples, but also aspect of the cells in the tissue had a significant influence on stiffness. Samples with smaller, less elongated cells have a broader transition zone and a lower strain at maximum stress than samples with long and big cells. Analysis of the images acquired at subsequent times in the test allowed the measurement of the cell deformations. Deformations of cells were found to be larger in transverse samples as compared to longitudinal samples. The information gained provided insight into factors determining the mechanical properties of vegetative tissues and will serve as input for the development of models to describe and to predict mechanical behaviour of plant tissues.

Keywords: *Allium cepa* L.; Tensile test; Elasticity modulus; Strength; Cell structural parameters

1. Introduction

Consumers nowadays expect fruit of premium quality, and to provide high quality fruit is an important challenge for producers, cool store operators and retail organisations. Texture is an important quality attribute of many fruit—consumers prefer firm, crispy and juicy fruit above soft and mealy fruit. Also, mechanical damage in the chain from producer to consumer affects the quality of the fruit to a large extent and inevitably leads to a considerable loss of its commercial value. Damage can be caused by impacts, vibrations, static loads and friction. It is mandatory to be able to

* Corresponding author. Tel.: +32 16 322732; fax: +32 16 322955.
E-mail address: els.vanstreels@biw.kuleuven.be (E. Vanstreels).

0925-5214/$ – see front matter
doi:10.1016/j.postharvbio.2005.04.004

identify the relevant mechanical loads and predict the damage they induce in order to be able to optimise stacking patterns, handling procedures and packaging materials. Both texture and damage susceptibility are determined by the mechanical properties. Classical approaches to study mechanical properties of vegetative tissues regarded the loaded object as a (non)linear, (visco)elastic continuum. However, fruit tissue is in reality a complex conglomerate of cells, and its integrity depends on the presence of an adhesive middle lamella between individual cells, the cellular turgor pressure, the mechanical properties of the cell wall and the presence of intercellular spaces. Therefore, a micromechanical approach is best suited to understand the relative importance of these cellular and histological attributes on the overall mechanical behaviour of the fruit.

As a first step towards the investigation of micromechanical properties of vegetative tissues, we selected onion epidermal peels as a study object. Onion epidermis consists of only one cell layer and is easy to isolate and manipulate. Micromechanical experiments on onion epidermal peels have been reported in the literature (Ng et al., 2000; Wilson et al., 2000; Wei et al., 2001). Ng et al. (2000) examined the chemical composition of the cell walls of different onion tissues, including the upper epidermis of fleshy scales, in relation to their tensile strength and notch sensitivity. Wilson et al. (2000) used a mechanical creep apparatus and Fourier-transform infrared spectroscopy to study cell wall polymer orientation, demonstrating that cellulose and pectin show distinct reorientation as cells were elongated. Wei et al. (2001) studied elasticity and load bearing ability of strips of onion epidermis.

Simultaneous observations of the structural parameters of the cells in the tissue in relation to micromechanical properties have not been made. In this work, a detailed analysis of micromechanical properties is presented. Moreover, we study the variation in these properties of epidermal peels originating from different onion scales, showing differences in cell structural parameters, and for different orientations of the samples. The insights gained will prove valuable when developing mathematical models based upon the histological properties of tissues to predict strain and failure of fruit tissue as a consequence of static loading and impact.

2. Materials and methods

2.1. Plant material

Strips of onion (*Allium cepa* L.) upper epidermis were isolated from the equatorial region of the bulb in a direction parallel with the vascular bundles. The first outer scale of the onion bulb was removed and discarded and only fleshy, non-dried scales were used. In total, five onions, five different scales (starting from the outside) of each onion and two samples per scale were analysed. Epidermis strips (2 mm wide, approximately 20 mm long) were cut with razor blades and carefully removed with forceps. After isolation, they were immersed in distilled water for at least 12 min to allow the cells to reach full turgor and to allow any induced stress from the removal step to relax.

In a second experiment, epidermal strips were cut in two different orientations: one direction parallel with vascular bundles (longitudinal samples) and another direction perpendicular to vascular bundles (transverse samples). Longitudinal and transverse samples were isolated directly adjacent to one another. After isolation, the strips were treated as mentioned above. Twenty-six samples originating from three onions were analysed.

2.2. Mechanical tests

Epidermis strips were clamped in the grips of a miniature tensile stage (Deben Microtest, Suffolk, UK), the part of the strip in the grips being supported by a wet filter paper (Fig. 1), which improved ease of handling and clamping. The grips were positioned at minimal distance, so that the gap between them was 10 mm, which thus ensured a consistent gauge length of the samples of 10 mm. The strips were humidified again

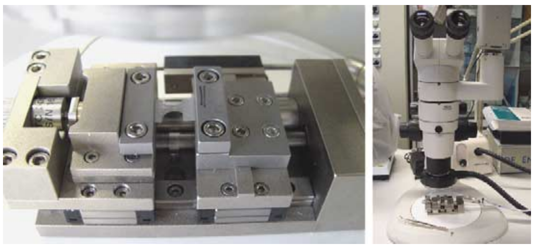

Fig. 1. Miniature tensile stage. (Left) Detail with sample positioned between the grips. (Right) Positioned underneath stereomicroscope.