Assessment of Mechanical Damage to Tropea Red Onion PGI During Processing

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Abstract. The commercial value of onions "Cipolla Rossa di Tropea Calabria PGI" is also determined by the absence of external imperfections and the management of the harvest and post-harvest phases is crucial for the product to maintain the quality standards preferred by consumers. Improper physical handling, dropping and shocks during harvesting, grading, packing and transport can cause structural, tissue and cell damage to the vegetable's commercial quality and shelf-life increasing the growth of microorganisms and susceptibility to decay. Damages can be caused by impact, compression, abrasion, puncturing, or maybe caused by the combined action. Imitative rheological (dynamometric) measurements can be very useful for studying the physical and structural properties of food products to manage handling, processing, quality control, and evaluation of sensorial characteristics. Rheological analyses are based on the measurement, carried out under controlled flow or deformation conditions, of the material's response to controlled mechanical stresses. The objective of this paper is to test spring onion response to mechanical stresses causing compression and penetration damage simulated in the laboratory using a texture analyser.

Keywords: Texture Profile Analysis (TPA), Spring onion, Hardness

1 Introduction

Onion (*Allium cepa* L.) is a vegetable biennial bulb crop belonging to the Amaryllidaceae family. Onion is widely known and cultivated as a functional food for its bioactive compounds [1-2] and is second only to tomato as the most economically important crop in both world and local markets [3]. In the Calabria region (Southern Italy) the organoleptic properties [4] and the presence of nutraceutical compounds are the characteristics which contribute to defining Tropea red onion as a "functional food" [5]. Indeed in 2008, Tropea red onion obtained the mark European Protected Geographical Indication "Cipolla Rossa di Tropea Calabria PGI".

The commercial value of onions is largely determined by their visual quality, especially skin colour, given consumers' sensitivity to quality [6-7]. Therefore, management of the harvest and post-harvest phases is crucial for the product to maintain the quality standards preferred by consumers [8]. Moreover, onions are a highly perishable vegetable and subject to post-harvest losses, having a high water content but a low dry matter content [9]. Good quality onions must have intact, undamaged and clean skin, free of pathogens and of the colour expected for that variety [7]. In the case of Tropea red onion three product types can be distinguished i.e. Tondo Piatta (early ripening), Mezza Campana (medium ripening) and Allungata (late ripening). They are divided into three typologies: Cipollotto (Spring Onion), which is pinkish-white-purple in colour; (Fresh Onion); Cipolla da Consumo Fresco (Fresh Onion), which is white-red to purple; and Cipolla da Serbo (Onion for Preserving), which is purple-red. Improper physical handling, dropping and shocks during harvesting, grading, packing and transport can cause structural, tissue and cell damage to the vegetable's commercial quality and shelf-life increasing the growth of microorganisms and susceptibility to decay [10]. Damages can be distinguished in damages by impact, compression, abrasion, puncturing, or maybe caused by the combined action [11-12]. Impact damage occurs when an object hits a surface with sufficient force to break or even separate cells and its extent and volume are inversely proportional to the rigidity of the fruit/vegetable's surface (and its state of ripeness) [13]. The impact generally causes a bruise or crack on the product surface [11]. In the case of onions, impact damage can occur during harvesting (e.g. during packing for transport to the farm) and during transport where vibrations create possible harmful interactions between the vegetables and the walls of the containers [14-16]. Generally, impact damages are considered the most severe in fruit/vegetable handling [17].

Cracks can also be caused by compression damage and can occur during the packaging stage, for example, when a certain amount of product is forced into a container that is too small [11]. Abrasion damage can be caused by frictional actions either during harvesting during excavation and extraction from the ground or during the packing operation [11]. Penetration damage that is a cause of increased susceptibility to disease and water loss is more likely when harvesting is mechanic [18]. Damage can then be quantified based on changes in mechanical parameters by comparing the effects of machining or test conditions on the values of these parameters [11].

Imitative rheological (dynamometric) measurements can be very useful for studying the physical and structural properties of food products to manage handling, processing, quality control, and evaluation of sensorial characteristics [19]. Rheological analyses are based on the measurement, carried out under controlled flow or deformation conditions, of the material's response to controlled mechanical stresses (abrasion, compression and penetration). Rheology thus includes the study of the statics of elastic bodies; that is, it is assumed that the biological material behaves as a homogeneous and isotropic body subjected to tensile, compressive or shear stresses, and the possible time-dependent deformations due to the action of the stresses are thus neglected [20]. The rheological characteristics of foodstuffs also include their mechanical behaviour, i.e. the response to the various stresses to which they are subjected, neglecting, to a first approximation, the possible increase in deformation over time when the material is constantly subjected to these stresses [21].

The objective of this paper is to test spring onion response to mechanical stresses causing compression and penetration damage simulated in the laboratory using a texture analyser. The textural parameter of hardness was calculated from the Texture Profile Analysis (TPA) curves and defined as the maximum peak force (g or N) during the first compression cycle.

2 Materials and methods

To assess the firmness of the Tropea Red Onion PGI, a series of compression and penetration tests were carried out on Tondo Piatta (early ripening) variety (Fig. 1).

Fig. 1. Spring onions used for rheological tests.

The aim was to establish action thresholds to not damage the bulbs. The tests were carried out at room temperature using a TA-TX.*plus* Texture Analyser (Stable Micro Systems Ltd., Godalming, Surrey, UK). In compression tests, the sample was loaded between two plates, a force was applied and the deformation was recorded. The cycle included compression, decompression and a second compression. This revealed changes in the structure of the sample. These tests assessed the material's compressive behaviour, plastic flow and ductile failure limit. Compression tests are based on uniaxial compression of the onions through a cylindrical probe with a flat head taking into account that the diameter of the probe must be larger than the diameter of the object undergoing the compression test. The compression test was conducted using a 50-mm cylindrical stainless-steel probe (Fig. 2).

Penetration tests used cone penetrometers to measure stress-strain properties with a 5 mm metal cone inserted into the specimen at a constant speed and force.

For both tests a 20 mm index was used until the breaking point was reached, with a test speed of 2 mm/sec and a trigger force of 5 grams, the probes were applied in triplicate. The hardness textural property was calculated in Newton (N).

Fig. 2. Texture Analyser used during compression test.

Before proceeding with the tests, the onions were classified by calibre, and successively for each onion the diameter and height were measured. All samples belong to category I (good quality, compact and hardy, free from swellings and root tufts). In addition, the content of total solids and moisture content were measured on each sample (Tab.1).

Table 1. Dimensional parameters of onion samples groups (average ± st.dev.).

Groups	Diameter (mm)	Length (mm)	Total solids (%)	Moisture content (%)
1	≤ 40	70.33±9.07	6.94±0.37	93.05±0.37
2	≥ 41	59.33±12.7	7.10±0.4	92.89±0.4

3 Results and Discussions

Figures 3-4 show an example of compression and penetration results and the damages obtained during trials. The thresholds found during the compressions tests were equal to 374.24 ± 98.51 N for group 1 and 484.76 ± 88.51 N for group 2 in the compression test. The first deformation stage is an elastically one, that consists in a fast linear increasing followed by a fast decreasing; this condition is repeated, albeit with slightly lower values, in the second descent of the plate, thus expressing a phase of freshness of the spring onions. The same freshness condition is recorded for penetration tests, where values were equal to 24.95±2.49 N for group 1 and 30.62±4.03 N for group 2. Guiné & Barroca, 2011 [22] for onions with a moisture content of 90.02% found an average hardness of the fresh onion of 12.87 (± 2.24) N performed by cylindrical samples (diameter 10 mm, height 5 mm) using a flat 75 mm diameter plunger, with a 5 seconds interval between cycles. Kefale et al., 2023 [23] based on the method in [24] using a 2 mm cylindrical probe with a speed of 2 mm/s and a penetration distance of 5 mm found a hardness equal to 15 N. The results highlight that materials of a biological nature have very complex internal structures, which may influence the results of the texture analysis (as shown by the standard deviation in compression tests), just by changing the orientation of the fibre arrangement [22,25]. The results obtained, compared to those of the two studies mentioned above, showed much higher thresholds for the compression and penetration tests. This can be explained by differences in product typology (spring onions in our case study). This results in differences in texture that affect the susceptibility to impact during processing.

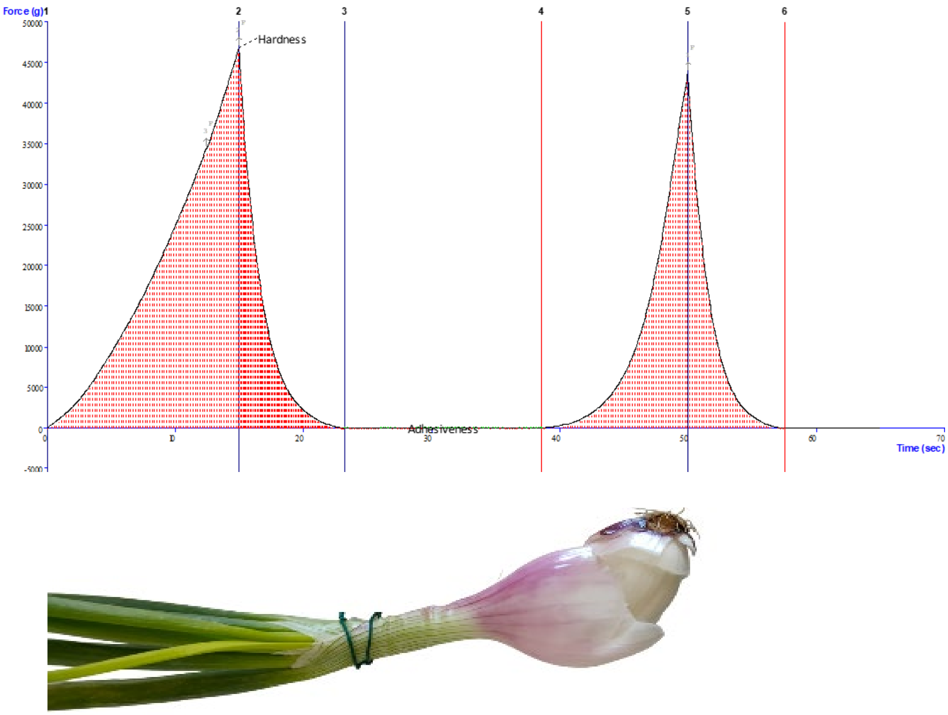

Fig. 3. Example of compression graphic (top) and damage (bottom)

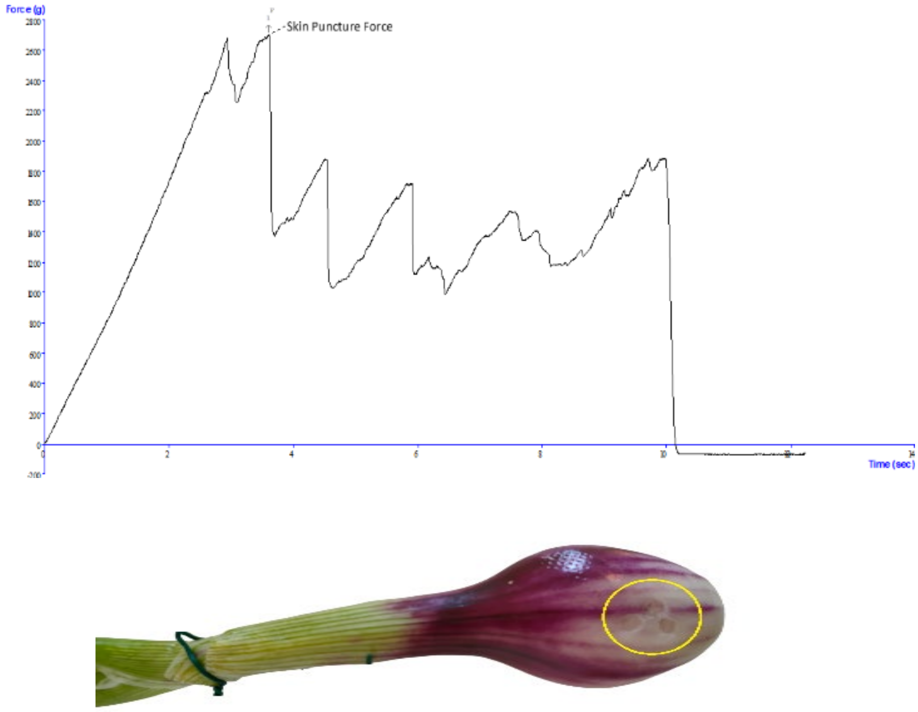

Fig. 4. Example of penetration graphic (top) and damage (bottom).

In any case, comparing the results obtained in terms of force required to damage spring onion, similar studies conducted on other products showed lower threshold values. For example, tests performed on tomatoes showed values of less than 5 N considered a mass averaging more than 100 g to a maximum of about 160 g [26,27]. Concerning bruising damage, one of the most common types of damage to which fruit and vegetables are exposed, mass also influences susceptibility to bruising, and it is known that the impact energy is directly dependent on the falling mass [25]. This greatly influences the impact phenomenon and the macro- and microstructural properties of the produce. In this respect, the thresholds measured on spring onions were higher both for a larger area in compression tests and for a localised area in penetration tests, which is cautiously reassuring as such (relatively) strong impacts are possible but unlikely, at least during post-harvest operations carried out by machinery. At this point, the greater or lesser risks will depend on whether or not operators are careful during the transport and handling steps associated with this stage [12]. Li et. al, 2017 [28] report some mathematical models to express theories of compression by a rigid plate on an approximately spherical fruit. Some of these models are based on the assumption that the contact area is circular, others that it is elliptical. Still others assume that the radius of the contact area is insensitive to the choice of contact conditions and that the onset of yielding of ductile materials occurs along the line of symmetry where stress is maximum. It is unclear which model is most accurate/suitable for predicting damage mechanics, which is even truer for the onion, which has a layered structure. To limit this damage and preserve the intrinsic quality characteristics (nutritional, organoleptic and sanitary), it is necessary to optimise the harvesting and post-harvesting operations, to avoid impacts equal to the values identified. After harvesting, the onion bulbs must be stripped of their soil-stained outer tunic and the tails cut to a length of between 30 and 60 cm before being placed in cardboard, plastic or wooden crates, ready for sale. These operations are often carried out with the aid of mechanical plants and are labour-intensive. Particular attention must therefore be paid to all stages of the supply chain, both where operations are completely manual and where they are carried out with plants, that are often assembled and not highly specialized (Fig. 5).

Fig. 5. Plant for post-harvest operations

This underlines, on the one hand, to ensure that the technicians responsible for managing the processing plants are properly trained and, on the other hand, to have a specialised workforce capable of handling the product correctly.

4 Conclusions

The severity of damage to agricultural products is related to the height of the fall, the number of impacts, the type and size of the impact surface, etc. This research has highlighted some critical limits that should not be exceeded during harvesting and post-harvesting operations to avoid damage to production. It should also be remembered that the mechanical properties of agricultural products are highly dependent on variety, agronomic parameters and climatic variations during the growing season. Further studies are needed to assess the extent of the impact along the processing chain and to identify critical points in the chain, taking into account, for example, that the plants used in postharvest operations are very complex and different from each other. In addition, superficial mechanical damage has repercussions within the fruit tissues that affect the shelf-life of the product itself, particularly in terms of loss of bioactive compounds, firmness, sugar and acidity. Due to the nature of these tests, however, they do not provide us with an understanding of the mechanisms of force-strain and breakdown at the cellular level. However, the idea that bruising susceptibility can be characterised by a single mechanical parameter is somewhat limiting, as it depends on many factors, that should be investigated in a multidisciplinary way

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