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Quality characteristics of air-dried apple rings: influence of storage time and fruit maturity measured by time-resolved reflectance spectroscopy

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Abstract

With the aim of studying the influence of maturity and of cold storage time on the quality characteristics of air-dried apple rings, 60 apples (cv Pink Lady®) were measured at harvest by time-resolved reflectance spectroscopy (TRS) at 670 nm, ranked on the basis of decreasing absorption coefficient at 670 nm (μ_a670, increasing maturity) and hence classified based on the ranking order as less mature (LeM), medium mature (MeM,) and more mature (MoM). The sixty fruit were, then, randomized into 3 batches corresponding to 3 storage times (0, 3 and 5 months in normal atmosphere at +1°C), and, at each storage time, 3 rings/fruit were air-dried at 80°C up to a constant weight using a pilot air circulated drier. Quality characteristics of fresh fruit and of air-dried rings were analysed by ANOVA and PCA statistical analyses. Stored fruit compared to fruit at 0m were softer, had lower stiffness and energy-to-rupture, and higher soluble solids content (SSC), relative intercellular space volume (RISV) and L^*_f. LeM class had lower SSC and dry matter, and the MoM class higher a^*_f and lower b^*_f than the other two classes. 3m-Apples showed the highest differences with respect to fresh ring in browning index (BI), total colour, chroma and hue, compared to fruit processed at 0m and 5m. Air-dried rings from less mature apples (i.e. those processed at 0m and of LeM class) had higher F_{max}, E_{mod}, E and BI than those from more mature fruits (i.e. those processed after storage and of MoM class). PCA underlined the positive relationship between mechanical characteristics of fresh fruit with those of dried rings and ring shrinkage, which were opposite to RISV, SSC and weight loss.

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Keywords: raw material selection; TRS; fresh fruit mechanical characteristics; crispness; dried rings colour

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1. Introduction

Recently new interest has arisen in the field of dehydrated apple products, used mainly as snack food [1]. Drying is a process involving heat and mass transfer that can cause physical and chemical alteration of the material. The stress developed when water is removed from the fresh material causes shrinkage and change in shape, both of which influence the porosity of the dried material and its rehydration properties [1-2]. Other consequences of the drying process involve changes in the reological properties of the product, which are bound to changes in composition, phase transition of the material, as well as to microstructural changes due to loss of cell turgor pressure and cell breakage [3]. Moreover, pigment concentration and/or degradation cause changes in colour (browning) [4], whereas the chemical degradation of nutrients leads to a quality deterioration of the final product [1]. These changes depend on various technological factors, and also on the properties of the raw material (cultivar and maturity degree). As for apples, in a previous study it was found that air-dried Pink Lady® rings had a more rigid and stiff texture than those from Golden Delicious cultivar, which in contrast had a more brittle texture [5]. Furthermore, it was shown that the non-destructive assessment of internal quality of fruit can be obtained by measuring the absorption and scattering optical properties of tissue using time-resolved reflectance spectroscopy (TRS) [6]. In apples, the absorption coefficient (μ_a) measured at 630 nm has been linked to fruit maturity: apples with higher μ_a630 had lower fruit mass, lower percent blush both at harvest and after cold storage, and fruit classified as more mature by TRS had less titratable acidity at harvest and more soluble solid content (SSC) after storage [7]. Within the same harvest, high μ_a630 fruit (i.e. less mature ones) had at harvest a less advanced breakdown of insoluble protopectins to soluble pectins, compared to the low μ_a630 ones (i.e. more mature fruit) [8]. At sensory analysis, low μ_a630 apples at the end of storage and after 7 days of shelf life were perceived sweeter, more aromatic and were more appreciated by panellists compared to high μ_a630 fruit [7]; the absorption and reduced scattering coefficients at 630, 670, 750 and 780 nm were related to sensory apple quality, and different models were created for the non-destructive assessment of the sensory characteristics related to fruit structure (firm, crispy, mealy, juicy) and flavour (sweet, sour, aromatic) [9].

This work aimed at studying the influence of TRS maturity and of storage time in normal atmosphere on the quality characteristics of air-dried apple rings, focusing on the relationship between the texture properties of fresh fruit and the colour and mechanical properties of dried apple rings.

2. Materials and Methods

Sixty apples, cv Pink Lady®, were measured at harvest by TRS at 670 nm (close to the absorption peak of chlorophyll-a) using a broad band TRS system developed at Politecnico di Milano [6], ranked on the basis of decreasing μ_a670 (increasing maturity) and hence classified based on the ranking order as (class, ranking, μ_a670, mean ± std err) less mature (LeM, rank 1-20, 0.0492 ± 0.00064 cm^{-1}), medium mature (MeM, rank 21-40, 0.0401 ± 0.00064 cm^{-1}) and more mature (MoM, rank 41-60, 0.0347 ± 0.00064 cm^{-1}). The sixty fruit were, then, randomized into 3 batches corresponding to 3 storage times: harvest (H, 0 m), 3 and 5 months in normal atmosphere at +1°C. At each storage time, three 5 mm thick rings/fruit were air dried at 80°C up to a constant weight using a pilot air circulated drier. Fresh fruit were analysed for pulp mechanical characteristics (firmness, stiffness and energy-to-rupture, E_f), relative intercellular space volume (RISV, [10]), soluble solid content (SSC) and dry matter (DM). Raw and dried rings were analysed for colour and geometrical features by Image Analysis [11]. The mechanical properties (ring hardness, F_{max}, crispness coefficient, E_{mod}, and energy to break point, E) of dried rings were measured by bending-snapping test [5] and moisture content (u) was determined by NIR [12]. For each ring, weight loss, shrinkage indices (area, A/A_f; thickness, L/L_f), percent area shrinkage (shrA), browning index (BI, [13]) and colour, hue, chroma and BI differences (ΔE, ΔH, ΔC and $\Delta BI/BI_f$, [14]) were computed. Data