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# Overall quality of ready-to-eat pomegranate arils processed from cold stored fruit

Amedeo Palma[a], Alberto Continella[b], Stefano La Malfa[b], Alessandra Gentile[b], Salvatore D'Aquino[a,*]

[a] Institute of Sciences of Food Production, National Research Council, Traversa La Crucca 3, Regione Baldinca, Li Punti, 07040 Sassari, Italy
[b] Dipartimento di Agricoltura, Alimentazione e Ambiente, University of Catania, Via Valdisavoia 5, 95123 Catania, Italy

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ABSTRACT

The overall quality, titratable acidity, total solid soluble, total polyphenol, anthocyanin content, antioxidant activity, sugar content and juice color of ready-to-eat arils of 'Primosole' pomegranate processed at harvest and after 30 or 60 days of storage of whole fruit at 5 °C and 90% RH was assessed. Minimally processed arils were packaged in polypropylene trays (150 g each), wrapped with a polypropylene film to generate a passive modified atmosphere and stored at 5 °C and 90% RH for 10 days. In-package $CO_2$ was lower for those arils obtained from fruit with longer storage time while $O_2$ concentrations increased. Slight or not significant changes were detected in chemical and physical parameters during the 10 days of shelf-life of packaged arils, regardless the storage time of whole fruit, even when physiological disorders of the peel significantly reduced the commercial value of whole fruit along storage. Similarly, changes in sensory analysis were negligible and did not affect the eating quality.


## 1. Introduction

The commercial potential of pomegranate fruit (*Punica granatum* L.) is very high both for the several ways the fruit can be utilized and also for its chemical composition, nutritional value and pleasant taste. Pomegranate is classified as a non-climacteric fruit and maturation occurs in the plant prior to harvest. When fruit are picked before reaching the optimum maturity stage, the ripening processes are interrupted and the best quality characteristics cannot be achieved (Elyatem and Kader, 1984). Pomegranates are mainly grown for fresh consumption of arils, the edible parts of the fruit consisting of a juicy red–pink pulp surrounding the seeds, but in different countries they are also used in the beverage and food industry to produce flavouring and colouring agents, jams, jellies and even wines. Arils represent around 60% of total fruit weight and consist of about 80% juice and 20% seeds while juice contains approximately 85% water and 10% total sugars, mainly glucose and fructose (Lee et al., 1974; Al-Maiman and Ahmad, 2002; Shwartz et al., 2009). Other important compounds are pectins, about 1.5% and ascorbic acid. Pomegranates are also an excellent dietary source of polyphenolic antioxidants (Singh et al., 2002; Fawole et al., 2012). Epidemiological studies have shown the potential health benefits of pomegranate fruit consumption, mainly due to the biological activity of polyphenolic phytochemicals present in arils characterized by antioxidant, anticancer, and anti-inflammatory activity (Smith, 2014; Sreeja et al., 2014). The soluble polyphenol content depends upon several factors such as cultivar, climatic and agronomic conditions. They are composed by anthocyanins (delphinidin 3,5-diglucoside, cyaniding 3-glucoside, cyaniding 3,5-diglucoside, pelargonidin 3-glucosides and pelargonidin 3,5-diglucosides), ellagic acid glycosides (ellagic acid glucoside, arabinoside, and rhamnoside), free ellagic acid, ellagitannins (several punicalagin isomers, punicalin, and some punicalagin polymeric forms), and gallotannins (Du et al., 1975; Gil et al., 2000; Noda et al., 2002). Polyphenols also influence the organoleptic properties of both arils and juice as they are responsible for the distinctive red pigmentation and mild astringency that is characteristic of pomegranates.

Pomegranate extracts are largely used as a source of bioactive phytochemicals in functional foods and as adjuvants in complementary and alternative medicine (Kessler et al., 2001; Seeram et al., 2006).

Despite the numerous health benefits and consumers' appreciation, the difficulty to extract the arils from the leathery husk and the fruit quality loss occurring over long storage in refrigerated conditions (due to husk scald, chilling injury, weight loss and microbiological spoilage), strongly hamper the potential consumption of fresh product and the marketable period of the fruit. Indeed, many consumers would prefer pomegranates to other

* Corresponding author.

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fruits, but the evolution of consumption habits, including the tendency to have meals away from home or snacking, makes it necessary the development of products that can easily be eaten anywhere where no knife nor plate are available. As a result, even people who at home do eat pomegranate, when away from home prefer other types of fruits. In this context, processing pomegranate fruit to obtain ready-to-eat arils, could be an important way to increase pomegranate consumption.

Ready-to-eat arils could also offer relevant social and economic opportunities for growing regions, by adding value to the final products, increasing employment for the high required work and might let the fruit be processed even after long storage periods.

The objectives of this study were: (a) to assess the changes, over a ten-day shelf-life period, of overall quality of ready-to-eat pomegranate arils, prepared from fruit at harvest time or after 30 or 60 days of storage at 5 °C, and (b) to compare the correlation marketable quality changes of whole fruit along the storage period with overall quality changes of ready-to-eat arils.

## 2. Materials and methods

### 2.1. Plant material

Pomegranate fruit (*P. granatum* L.) cv. Primosole, a new accession from Sicilian germplasm with sweet arils and soft seeds (La Malfa et al., 2009), were harvested (mid-October) at optimum maturity and quality stage, in a commercial orchard located in central-east Sicily receiving standard horticultural practices. Arils to be prepared as ready-to-eat were extracted from fresh fruit, after 24 h at 20 °C from harvest, or after a storage period of 30 or 60 days at 5 °C and 90% RH. The choice of storage conditions was based on results of previous studies reported in the literature (Elyatem and Kader, 1984; Kader et al., 1984). To prevent microbiological spoilage, before being stored, fruit were dipped for 30 s in an aqueous mixture at 20 °C containing 600 mg $L^{-1}$ of fludioxonil (Scholar Flowable 20, Syngenta, USA) (D'Aquino et al., 2010).

### 2.2. Respiration and assessments of whole fruit

Fruit respiration rates were measured at time 0 (after 24 h conditioning at 20 °C from harvest), the end of storage at 5 °C and 24 h after their transfer to 20 °C; to do so six fruit were individually closed for 4 h, at 5 °C, or 1 h at 20 °C into 1-litre jars fitted with one rubber septum to allow withdraw air samples. Carbon dioxide was determined using a $CO_2/O_2$ analyser (Servomex 1450B3, Crowborough, England) fitted with a coupled infrared/paramagnetic detector (D'Aquino et al., 2001). Respiration rates were expressed as mL $CO_2$ $kg^{-1}$ $s^{-1}$.

At harvest individually numbered fruit were weighed and re-weighed after 30 or 60 days of storage to determine the percentage of weight loss; 50 fruit were used at each inspection.

Peel alterations, in the form of husk scald or brownish pitted spots were evaluated using a 0–4 subjective scale, where: 0 = normal (no damage); 1 = slight (sporadic tiny scattered pits or faint scald covering less than 10% of fruit surface); 2 = moderate (a few tiny scattered pits or scald covering up to 20% of the fruit surface); 3 = severe (extensive pitting and brownish scalded area covering up 50% of fruit surface; 4 = very severe (spread coalescing and depressed brownish-black pits and deep brown scald spread over 50% of fruit surface. The peel alteration index was determined for each treatment by multiplying the number of fruit in each category by their score, and then dividing this sum by the total number of fruit assessed. Overall appearance was based on a 9-point scale, where: 1 = very poor; 3 = poor; 5 = good (limit of marketability); 7 = very good; 9 = excellent.

All fruit showing any signs of microbiological attack were considered as decayed and decay incidence was expressed as percentage of rotten fruit.

For each storage time a total of 250 fruits were used to determine decay incidence; peel alterations and overall appearance were determined on the remaining fruit, free of microbiological infections.

### 2.3. Fruit processing and packaging procedures

Two hundred fifty fruit at harvest time and all fruit free of decay and scored less than 4 for peel alterations after visual assessments (236 fruit after 30 days and 170 fruit after 60 days), were divided into three groups to prepare arils. The extraction was done manually by carefully cutting the husk along the equatorial zone without damaging the arils to facilitate fruit opening and separation of arils from the white membranes. Arils of each group of fruit were combined into three plastic bowls, washed in water added with 100 ppm of chlorine and then dried by soaking up excess water with absorbent paper (Gil et al., 1996). Arils were placed inside polypropylene trays (250 mL volume), approximately 150 g of product, wrapped with a polypropylene film (Termoplast oc/hs MY 40, Salerno, Italy, $O_2$ permeability 300 mL/$m^2$ d bar, $CO_2$ permeability 1000 mL/$m^2$ d bar) and held 5 °C and 95% RH for a 10-day shelf-life period. Packaging materials and storage temperature were chosen based on previous results (Palma et al., 2009). At harvest and after 30 or 60 days of storage, from each of the three bowls a group of 12 packages was prepared for chemical analyses, one group of 12 packages for sensory analyses and another group of 4 packages to determine in-package gas composition, for a total of 36, 36 and 12 packages, respectively. The 36 packages destined for chemical analyses were divided into four groups (one group for each sampling time of the 10-day shelf-life period) of 9 packages (3 packages from each bowl) which were used at each inspection time by combining the arils of the 3 packages of each bowl, which represented a replication, and conducting all analyses in triplicate. Similarly, the 36 packages prepared for sensory analysis were divided into 4 groups (one group for each sampling time) of 9 packages. Differently, as better specified below, in-packages gas composition was determined re-using the same packages (12) for the whole experiment.

### 2.4. In-package carbon dioxide, oxygen and ethylene

In-package gas composition was determined after 1, 2, 4, 7 and 10 days of shelf-life. Two 1-mL headspace samples, withdrawn from each package with a gas-tight syringe, were used to determine $CO_2$ and $O_2$ and $C_2H_4$ concentration, respectively. The number of used packages for each storage time was 12 and in-package gas composition was determined re-using the same packages at each sampling time of the ten-day of shelf-life. To prevent film tearing by the sampling needle and gases loss from the sampling hole, a silicon tape was stuck on sampling surface before and immediately after collection. Ethylene was assessed by a Varian 3300 GC equipped with a flame ionization detector (FID), Carbowax 20M 80/120 mesh Carbograph 1 AW 30 column (Alltech, Italy, Milan), the column temperature was 60 °C, injector 110 °C and detector 180 °C. Oxygen and $CO_2$ concentrations were determined by an Agilent 6890 gas chromatograph system (Alltech, Italy, Milan) equipped with a thermal conductivity detector (TCD), CTR I column 6′X1/4′ outher & 6′X1/8′ inner, the column temperature was 60 °C, injector 120 °C and detector 160 °C, carrier gas: helium.