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Post-harvest technological treatments of pomegranate and preparation of derived products

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SUMMARY – During the last few years, the activity in research and development on pomegranate fruit has aimed at the application of new post-harvest storage technologies to extend the storage life of pomegranates, keeping the original quality of the freshly harvested fruits. In this way research has focussed to the application of controlled atmospheres, the use of modified atmosphere packaging in polymeric films and the application of thermal treatments during the refrigerated storage. These technological treatments were applied to alleviate chilling injury symptoms which occur during the storage of pomegranates below 5°C. Although the industrial processing of pomegranate is still scarce, research on the development of new products such as minimally processed seeds, jams, juices and jellies has been carried out. This new sector of pomegranate industrial processing will allow the use of fruits with low commercial quality fruits (small size, bruised husks, non-commercial varieties, sun-burnt husks, etc.), that cannot be commercialised today in spite of having good quality juice and seeds, to the preparation of these new products.

Key words: Pomegranate, *Punica granatum*, Punicaceae, post-harvest treatments, chilling, intermittent warming, curing, modified atmospheres, minimally processed seeds, juice, jam, jelly.

RESUME – *"Traitements technologiques post-récolte des grenades et préparation de produits dérivés". Pendant ces dernières années, l'activité de recherche et développement sur la grenade a visé à l'application de nouvelles technologies de stockage post-récolte pour élargir la vie des grenades en emmagasinage, en conservant la qualité originelle des fruits fraîchement cueillis. De cette façon la recherche a été principalement axée sur l'application des atmosphères contrôlées, l'utilisation d'emballages de film polymère avec atmosphère modifiée et l'application de traitements thermiques pendant le stockage au froid. Ces traitements technologiques ont été appliqués pour atténuer les symptômes de dommages par froid qui surviennent pendant le stockage des grenades en dessous de 5°C. Bien que la transformation industrielle de la grenade soit encore rare, des recherches ont été menées sur le développement de nouveaux produits tels que les graines avec une transformation de quatrième gamme, les confitures, jus et gelées. Ce nouveau secteur de la transformation industrielle de la grenade permettra l'utilisation des fruits de qualité commerciale inférieure (petite taille, écorce meurtrie, variétés non commerciales, écorces brûlées par le soleil, etc.), qui ne peuvent pas être commercialisés actuellement malgré qu'ils possèdent des jus et des graines de bonne qualité, pour la préparation de ces nouveaux produits.*

Mots-clés : *Grenade,* Punica granatum*, Punicaceae, traitements post-récolte, réfrigération, échauffement intermittent, séchage, atmosphères modifiées, graines pour quatrième gamme, jus, confiture, gelée.*

Introduction

The activity of research and development on pomegranate has aimed in the last years at two main targets. Firstly, to the application of new refrigerated storage technologies (controlled atmospheres, modified atmosphere packaging, intermittent warming, curing, etc.), to extend the commercial life of pomegranates keeping, or even increasing in some instances, the original quality of the freshly harvested fruit. This kind of research has an immediate application, as pomegranates are mainly commercialised for the fresh fruit market, and in the case of Spain, is mainly for exportation to other European markets. On the other hand, research has also aimed at the search of new pomegranate-derived food products. These products are not yet commercially important, due to the lack of technological development for the industrial processing of pomegranates. However research has aimed at the production of new processed products, that can exploit those fruits with low visual quality (bruised, cracked, sun-burnt, small size), and those varieties that, although they have seeds and juice with enough quality, are not suitable for commercialisation in the fresh-fruit market.

Post-harvest treatments for pomegranate storage

Pomegranate commercial life means the time that this fruit can keep a certain quality level under specific storage conditions.

The physiological status and development of the fruit play an important role in the refrigerated storage and handling processes, aiming to minimise the quality loss. As a non-climacteric fruit, pomegranate does not ripen after harvest, and for this reason it has to be harvested when is fully ripened, when it shows the optimal organoleptic characteristics.

In pomegranates, the more intense the respiration, the faster is the decay. Temperature, relative humidity and atmosphere composition, are the environmental factors that, depending on the desired storage period, can be used to reduce the respiration and minimise the physiological and fungal decay losses (Ben-Arie *et al.*, 1984; Kader *et al.*, 1984).

It is evident that one of the main ways to extend the post-harvest life of pomegranates is reducing as much as possible the mechanical damage (bruises, scrapes, cuts, compression, etc.), with a careful handling.

Another essential way to prolong the commercial life of pomegranates is optimising the environmental conditions that will maintain the quality specifications of the fruits within economic margins.

Previous studies have demonstrated that temperature is the most important factor to control the respiratory activity, transpiration and the development of microbial pathogens. A fast pre-refrigeration using forced air is one of the simplest ways to extend pomegranate commercial life. This temperature has to be around 5°C to prevent the production of physiological disorders, during 2-3 months storage (Kader *et al.*, 1984; Artés, 1992).

The relative humidity is the second factor in importance. The key concept is the deficit in vapour pressure or difference between relative humidity of the environment. Temperature and relative humidity are closely related and the objective is minimising the weight loss without increasing the microbial development and decay. As pomegranates are commercialised without post-harvest treatments (washing, waxing, fungicides), the fruits must be gently brushed, and kept with a relative humidity around 90-95% if the fruits are healthy and clean (Artés, 1992).

New technologies and pomegranate storage

In the last few years research on pomegranate post-harvest storage has been addressed to the search of new physical treatments to prolong the commercial life of pomegranates. These treatments must keep the original quality of the fruit, avoiding fungal development, and the loss of quality characteristics (colour, flavour, texture) and nutritional properties (vitamins, antioxidants, health-promoting agents, etc.). These treatments modify the environmental conditions of pomegranate storage, and have an effect on the fruit physiology and biochemistry and on the development of micro-organisms that contaminate the fruit surface. In this way, the possible application of atmospheres with a gas composition different from the air (CO_2 enriched and/or reduced in O_2) has been explored. In addition, the use of thermal treatments for fruit conditioning and curing, and intermittent warming during cold storage to avoid fungal development and the physiological disorders that can develop as a consequence of the storage in temperatures below 5°C, have also been studied.

Controlled and modified atmospheres

It has been reported that during the post-harvest storage of pomegranates from Israel at temperatures below 6°C, chilling injury is observed, with symptoms including the appearance of depressions and browning in the fruit husk. This cold damage can be inhibited by storage in atmospheres with 2-4% O_2 and temperatures between 2 and 6°C (Ben-Arie and Or, 1986). The effect of post-harvest storage at 5°C under controlled atmospheres on pomegranate quality and incidence of chilling injury has been recently studied (Artés *et al.*, 1996). Pomegranates of cultivar 'Mollar' were stored up to 8 weeks at 5°C and under 95% relative humidity, and were later transferred to 20°C during 6 days to simulate the commercialisation period. Different controlled atmospheres were tested and the quality of the fruits was compared to that of the fruits stored in air. Storage under controlled atmospheres (10% O_2 and 5% CO_2; 5% O_2 and 5% CO_2; 5% O_2 and 0% CO_2) reduced weight loss, fungal decay and chilling injuries (husk surface scald). The storage in controlled atmospheres, however, reduced the vitamin C and sugars contents. Other studies on 'Wonderful' pomegranates stored in air enriched with 10 or 20% CO_2, showed that the colour of the seeds stored in air increased during refrigerated storage (10°C, 6 weeks), while the seed pigmentation was less intense in those of pomegranates stored in 10% CO_2, and even decreased in those fruits stored in 20% CO_2. This increase in seeds pigmentation was well correlated with the PAL activity of pomegranate seeds, a key enzyme of phenolic metabolism (Holcroft *et al.*, 1998). Nevertheless, these authors found that storage under atmospheres with a moderate CO_2 composition (10%) prolonged the storage life of pomegranates and kept the original quality, including an adequate seed colour.

The use of plastic packaging of whole pomegranates, or even pomegranate arils, in micro-perforated polypropylene bags, has also been studied. In these cases the respiration of pomegranates inside the bags, and the selective permeability of the polypropylene films for the different gases, in bags that are hermetically sealed, a modified atmosphere is generated around the fruit, atmosphere which is enriched in CO_2 and poor in O_2. It is important using films that allow reaching the adequate gas levels, to produce the expected beneficial effects, without triggering the fermentative metabolism that will lead to off flavours. In this context, very promising preliminary results have been obtained. Thus, it is possible to prolong the storage life of the fruits with an acceptable quality, and the water loss is considerably reduced as well as their effects on the fruit surface, showing the fruits an exceptional appearance during the commercialisation period. The modified atmosphere packaging technique has also been used with success for the storage of minimally processed pomegranate seeds (Gil *et al.*, 1996a,b), and for their preparation a patent has been developed in the Post-harvest and Refrigeration laboratory of the CEBAS (CSIC) Institute (Artés *et al.*, 1995).

Thermal treatments during cold storage

The studies on the storage of pomegranates under refrigeration has received little attention, although this fruit has a wide harvesting period in areas with moderate climates, and refrigeration is the only means to prolong the storage life of the fruit up to three months.

Pomegranate harvest starts in Spain in mid September to end in the middle of November for the late cultivars. Pomegranates are normally stored refrigerated for several weeks to extend the commercialisation until Christmas. However, during their storage several physiological and enzymatic disorders, and fungal attacks, can affect seriously the quality attributes. Spanish 'sweet' pomegranates can suffer chilling injury if they are stored for more than two months at temperatures below 5°C. This injury includes symptoms like browning of the rind, pitting, scald, an increased sensitivity to fungal development and decay, and internal discoloration and browning of the seeds (Artés, 1992). Some cultivars, i.e. 'Wonderful', can be stored without problems for 2 months at 5°C. The minimal safe temperature to store sweet pomegranates is 10°C (Kader *et al.*, 1984). This temperature, however, does not prevent fungal development. Previous studies have demonstrated that the conventional storage of 'Mollar' pomegranate at 5°C and 90-96% R.H. up to eight weeks, leads to an acceptable decrease in fungal decay losses, but the risk of chilling injury was not completely prevented. Storage under controlled atmospheres (5% CO_2 and 5% O_2) at 5°C and above 95% relative humidity for two months, improved the quality attributes of the freshly harvested pomegranate, although a moderate husk scald was observed (Artés *et al.*, 1996).

Intermittent warming treatments, that have proved useful in the prevention of chilling injury symptoms in other products, have been recently applied to pomegranates (Artés *et al.*, 1998a). In this case, 'Mollar de Elche' pomegranates were stored at 0°C and 5°C and 95% R.H., for 80 days. Intermittent warming treatments at 20°C were applied in cycles, one day every six days storage, followed by a commercialisation period of 7 days at 15°C and 70% R.H. While intermittent warming during the storage at 0°C prevented fungal development, although increased susceptibility to chilling injury symptoms, like pitting and husk surface scald, storage at 5°C reduced considerably the chilling injury symptoms although the fungal attack was not completely inhibited. The warming treatments led to very good results keeping the quality of pomegranates, especially when they were applied to pomegranates stored at 0°C.

Another technological treatment that is starting to be used with success in pomegranate is the pre-conditioning at moderate temperature (30-40°C) and high R.H. (90-95%) for a short period of time (1-4 days), a technique also known as curing, that is applied before the conventional refrigerated storage. As recently reported, a pre-treatment at 35°C and 90-95% R.H. applied for three days previously to a refrigerated storage during 80 days at 5 or 2°C and 90-95% R.H., reduced considerably the pitting and husk superficial scald (produced by the enzyme polyphenol oxidase) compared to control pomegranates without the pre-conditioning treatment. The effects observed were more marked when the conservation was carried out at 2°C than at 5°C, particularly during the additional period of one week at 15-20°C and 70-75% R.H., applied to simulate the retail sale period (Artés *et al.*, 1998b,c).

New products derived from pomegranate

In the last few years there has also been an increasing interest in the search for new pomegranate derived food products. As a result of this research new products have been developed. Among them we should mention the minimally processed pomegranate seeds ("ready-to-eat"), jams and marmalades, single-strength juices, jellies, juice concentrates, frozen seeds, seeds in syrup, etc.

For the production of most of these products it is important to develop a method for the industrial peeling of pomegranates, that makes possible the preparation of these products at a reasonable cost. There is already a pilot plant for the industrial peeling of pomegranates, that was developed by the Escuela Politécnica Superior de Orihuela, and that is actually under experimental process for the preparation of several of these products (P. Melgarejo, pers. comm.).

One of the main nuisances of pomegranate as a fruit is the relative difficulty in peeling, that makes difficult and tedious the preparation of its seeds. In addition, during hand-peeling, and due to the high content of polyphenols and oxidative enzymes in the fruit rind, the skin of the hands is stained brown, making this process an even more annoying task. It is for this reason that the development of "ready-to-eat" pomegranate seeds has been a challenge that has been approached by several research groups in Spain (Artés *et al.*, 1995) and the USA. Once the peeling problem is solved, the seeds have to be washed with solutions that guarantee the sanitation of the product reducing the microbial load, and that ensure their quality characteristics. These solution include chlorine (100 mg/kg), ascorbic acid (5 g/l), citric acid (10 g/l), and combinations of these (Gil *et al.*, 1996a). The best results with the cultivar 'Mollar de Elche' were obtained washing the seeds with the chlorine solution, followed by a mixture of ascorbic and citric acids, and storing the seeds at 1°C in polypropylene films that allowed the formation of a modified atmosphere appropriate for the conservation of these seeds. The preparation of seeds under very clean conditions and at temperatures close to 0°C prolonged the life of this product and maintained its quality (Gil *et al.*, 1996a). Storage at higher temperatures (4-8°C) produced seeds with lower quality and a shorter commercial life. When the effect of minimal processing and the subsequent storage on pomegranate seeds pigmentation were studied, an increase in pigments was observed during the storage at 0°C, while these decreased both at 4 and 8°C (Gil *et al.*, 1996b). Studies with the cultivar 'Wonderful' have shown that those seeds that had suffered mechanical damage during seed preparation, appeared soft and aqueous and were much more susceptible to microbial spoilage (Hess-Pierce and Kader, 1997). Seeds were stored in air and in controlled atmospheres of air with added CO_2 at 10, 15 and 20%, and at temperatures of 5 and 10°C. The commercial life of the prepared seeds was 8 days at 10°C and 12 days at 5°C. Atmospheres enriched in CO_2 helped to prolong the commercial life of the seeds.

In the field of pomegranate jams and marmalades, the stability of anthocyanin pigments in these products and the effect of thermal treatments on the quality of the products have been studied. As a general rule, it is necessary to establish the optimal thermal treatment (time/temperature), which guarantees the commercial sterilisation of the product and the inactivation of the oxidative enzymes, but preventing the production of brown polymers as a consequence of the Maillard reaction and the anthocyanin degradation. In general, the products obtained show an appealing colour, but a flavour which is quite dull, and by this reason we have suggested the use of pomegranate juice as an ingredient providing colour to other products that have an intense flavour, but a lack of pigmentation (strawberry jams) (Zafrilla *et al.*, 1998).

A related product that has been recently studied has been pomegranate jelly. In this case, the percentage of sugar added is smaller than that of jams and marmalades, and addition of jellying agents (pectins, agar, etc.) is necessary for the preparation of jellies, that generally maintain very well the colour characteristics of the original juice. The effect of the pH is essential for pigment stability and the colour of the prepared jellies. Therefore, it has been shown that jellies prepared with juices from sour pomegranates, have better colour and pigment stability than those produced with sweet pomegranates of cultivar 'Mollar'.

In the case of pomegranate juice, it has been shown that both the extraction and clarification process and the pH of the obtained juice (juices added of organic acids to decrease the pH), have marked effects on juice stability. Storage of frozen juice permits prolonging the juice life considerably, although it does not completely prevent pigment degradation and browning.

Other products such as frozen seeds, seeds in syrup, pomegranate spirits, etc. have also been studied, but not very intensely, and offer a very wide range of pomegranate derived products that will allow the use of low quality fruits that are presently discarded.

Finally we have to mention the possible use of pomegranate industrialisation wastes and residues for the extraction of phytochemicals that have an interest for nutrition and pharmacy. Pomegranate rinds are very rich in polyphenolic compounds (ellagitannins) which, as naturally occurring compounds, or as compounds obtained by transformation of the natural compounds, have a very intense antioxidant activity, and these could be used as ingredients in dietetic formulations. In addition, the ring and the seeds are very rich in fibre, whose nutritional quality has to be evaluated. These residues are also rich in alkaloids, aromatic compounds, and are an interesting source of enzymes. For these reasons, the field of pomegranate by-products is an interesting field to be exploited, once pomegranate industrialisation has become a reality.

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