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PACKAGING AND STORAGE OF POMEGRANATE FRUITS AND ARILS: THESIS REVIEW

[1]VENKATARAMUDU K, [2]SRINIVASULU B, [3]SWARAJYA LAKSHMI K

[1]College of Horticulture, Anantharajupeta, Dr. Y.S.R.H.U, Venkataramannagudem, West Godavari, Andhra Pradesh, India.

[2]Horticulture Research Station, Ananthapuramu, Dr. Y.S.R.H.U, Venkataramannagudem, West Godavari, Andhra Pradesh, India.

[3]College of Horticulture, Anantharajupeta, Dr. Y.S.R.H.U, Venkataramannagudem, West Godavari, Andhra Pradesh, India.

ABSTRACT

Pomegranate arils are rich in vitamin-C, anti-oxidants and polyphenols such as tannins and anthocyanins and hence considered good for health with anti-cancer properties. Pomegranate fruit is a non-climacteric fruit with relatively low respiration rate and produces trace amounts of ethylene. Generally, fruit has a long storage life ranging. However, the arils removed from fruits have short storage life owing to exposure to outer environment and tissue damage resulting from processing operations. Damage to arils, infact, leads to increase in rate of respiration and ethylene production rates, alters metabolic activity, increases the rate of deterioration of nutritional and sensory attributes and notably reduces the shelf-life. In order to meet the consumers present demand for fresh, convenient and high quality ready-to-eat arils, various processing techniques have been developed among which, modified atmosphere packaging along with low temperature storage are being increasingly employed to extend the shelf life of arils.

Keywords: pomegranate fruit, Arils, Packaging, Storage temperatures

INTRODUCTION

Pomegranate (*Punicagranatum* L.) popularly known as Anar is widely cultivated in India, Iran, China, Turkey, USA, Spain, Azerbaijan, Armenia, Afghanistan, Uzbekistan, Pakistan, Tunesia, Israel, dry regions of South East Asia, Peninsular Malaysia, the East Indies and Tropical Africa and gaining lot of attention world over, due to its high economic and nutritional values. The estimated global cultivated area of pomegranate is 3.0 lakh hectares with a production of 2.5 million tonnes (Patil *et al*. 2014). It is estimated that by 2025, the area under pomegranate would

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increase to 7.5 lakh hectares and the production is expected to increase by 10 fold and export by 6.97 fold (Krishna Kumar, 2014).

India is the world's leading pomegranate growing country with about 1.81 lakh hectares of area, 17.89 lakh tonnes of production and 9.88 tonnes of productivity per hectare. Pomegranate cultivation today is a highly lucrative and remunerative agriculture business in India. The alluring monetary return per unit area from this crop has resulted in steady increase in area, production and export of pomegranate during last two decades. The major pomegranate growing states in India are Maharashtra (1.28 lakh hectares), the Pomegranate Basket of India (Annual Report of NRCP, 2015-16) followed by Karnataka (19040 ha), Andhra Pradesh (7910 ha) and Gujarath (9380 ha) (Horst, 2016). In recent past, pomegranate cultivation has been gaining momentum in Rajasthan, Odisha, Chhattisgarh, Uttarakhand, Madhya Pradesh, Himachal Pradesh, Tamil Nadu, Mizoram, Nagaland, Lakshadweep, Jharkhand and Jammu and Kashmir. There are more than twenty five pomegranate varieties grown in different parts of India. However, the varieties viz.,Bhagwa, Ganesh, Ruby, Phule Araktha and Mridula are grown on commercial scale in India.Among these varieties, Bhagwa contributes to more than 90% of the area and production.

The fruit of pomegranate is symbolic of plenty and very much liked for its cool, refreshing juice and valued for its nutritional properties. Pomegranate is currently ranked 18th interms of fruit consumed annually in the world. It is predicted that as a result of its health benefits, availability in convenient pre-packed aril form and the improvement form of cultivator's selection it will move to 10th place in the next 5 years (Sudarshan *et al*. 2013).

Botanically, the fruit of pomegranate is known as 'Balusta' which is a modified berry. The edible part of fruit is called 'aril' and constitutes 52 per cent of total fruit (w/w), comprising 78 per cent juice and 22 per cent seeds (Kulkarni and Aradhya, 2005). Arils are rich in vitamin-C, vitamin-K, anti-oxidants and polyphenols such as tannins, quercetin and anthocyaninsand henceconsidered good for health with anti-cancer properties (Seeram *et al.* 2006 and Adams *et al.* 2006). Pomegranate seeds are excellent source of dietary fibre and also rich source of various minerals and micronutrients viz., K, P, Mg, Ca, Zn, Mnand Fe (Hobani *et al.* 2004). Pomegranates have very little fat and do not contain cholesterol.The arils are also used as garnish for desserts and salads (Al-Maiman and Ahmad, 2002). Dark coloured pomegranate arils are related to a higher anti-oxidant activity compared to light coloured arils (Tzulker*et al.* 2007).

Pomegranate is commercially grown for its sweet acidic fruits which are mainly consumed fresh (table purpose) by extracting the arils or utilized as processed products namely juice, yoghurts, syrup, grenadine, anardana, anar-rub, jam, jelly, wine, carborated beverage,*etc*. The difficulty encountered in separating the edible arils from pomegranate fruit has several limitations for its

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direct consumption unlike the other fruits e.g., oranges, banana, grapes *etc*. (Pal and Gaikwad, 2014). The supply of arils of pomegranate in ready-to-eat form would be convenient with desirable alternative to the consumption of fresh fruits and may further increase pomegranate demand by consumers. The ready-to-eat pomegranate arils offer an appealing product compared to the whole fruit and increases the prospect of production and consumption (Gil *et al*. 1996a and Gil *et al*. 1996b). Hence, removal and processing of pomegranate arils is of great importance for convenience of the consumers. The demand for minimally processed pomegranate arils (ready-to-eat arils) is increasing in domestic as well as international markets, because of high economic importance, healthiness and their desirable characteristics as compared to whole pomegranate fruit and changing food consumption pattern.

Pomegranate fruit is a non-climacteric fruit with relatively low respiration rate and produces trace amounts of ethylene (Caleb *et al*. 2012). The average rate of respiration of fresh arils varies with pomegranate cultivar. Generally, pomegranate fruit has a long storage life ranging from 2 to 7 months, depending on the cultivar and storage conditions. However, the arils extracted from fruits have short storage life owing to exposure to outer environment and tissue damage resulting from processing operations. Damage to arils, infact, leads to increase in rate of respiration and ethylene production rates, alters metabolic activity, increases the rate of deterioration of nutritional and sensory attributes and notably reduces the shelf-life.

In order to meet the consumers present demand for natural, fresh, flavourish, convenient and high quality ready-to-eat pomegranate arils, various processing techniques have been developed among which, minimal processing and modified atmosphere packaging along with low temperature storage are being increasingly employed to extend the shelf life of arils by maintaining the quality.

Package and storage go hand in hand. Storage of products is influenced by the kind of packaging material used besides storage temperatures. Packaging protects the arils, serves as an alternative measure for controlling diseases and provides structural support for convenient storage and transport. Various storage and packaging applications have been under study by research workers for safe storage of pomegranate arils of different varieties. Many types of packaging material have been used which include polypropylene (PP), low density polyethylene (LDPE), high density polyethylene (HDPE), metalized polyester (MP) bags, heat seal trays with oriented polypropylene film (OPPF), rigid polystyrene vessels (RPV), perforated polypropylene trays (PPT), polyethylene terephthalatepacks (PETP), polyethylene standing pouch (PESP), polypropylene modular mates (PPMM) *etc*.

With regard to storage temperatures, the main principle underlying low temperature storage is to slow down the physiological and biochemical activities of the stored produce. The common

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method employed for enhancing storage life of fruits and their products is to keep them under ideal temperatures to extend the shelf life. Refrigeration is the only known economical method for safe storage of fruits and fruit products.

At present, the main impediment in pomegranate ready-to-eat arils trade is short shelf life, losing their sensory and microbial quality quickly after extracting from the fruit and the only one way to extend the storage period of arils sufficiently for longer period without affecting their quality is by use of proper packaging material and storing at ideal temperature.

The recent past documented results pertaining to the influence of packaging material and storage temperatures on the quality and shelf life of pomegranate fruit as well as arils are reviewed in this chapter

EFFECT OF PACKING MATERIAL ON QUALITY AND SHELF LIFE OF POMEGRANATE FRUITS

Gil *et al*. (1996) reported that arils of pomegranate cv. Mollar de Elche, washed with chlorine solution, followed by a mixture of ascorbic and citric acid and stored at 1°C in polypropylene films prolonged the shelf life by maintaining their quality.

Gil *et al*. (1996a) studied the effect of packing material on pomegranate arils packed in perforated oriented polypropylene (POPP) and unperforated polypropylene (UPP) package bags and stored at 1°C for 7 days. They observed that unperforated OPP bags maintained the pigments better compared to perforated OPP bags. However, when the storage condition was extended for additional 4 days at 4°C to mimic domestic storage, the arils were better preserved in the perforated films. Artes *et al*. (2000) studied the quality of Spanish 'Mollar de Elche' sweet pomegranates (*Punicagranatum* L.) stored at 2°C to 5°C for 12 weeks in unperforated polypropylene (UPP) film of 25 µm thickness in modified atmosphere packaging (MAP) and perforated poly propylene (PPP) film of 20 µm thickness and conventional cold storage. All treatments suffered a decrease in total anthocyanin content at the end of shelf life. MAP strongly reduced the water loss and chilling injuries without incidence of decay.

Artes *et al*. (2000 a and b) studied the effect of different thermal treatments and packaging material in pomegranate cv. 'Mollar de Elche'. They observed minimum weight loss of 0.07 per cent, when exposed to thermal treatment prior to storage at 5° or 2°C for 12 weeks, whereas, weight loss is 1.15% to 1.34% in unpacked (control).

Garcia *et al*. (2000) studied the respiratory intensity (RI) of minimally processed pomegranate 'Mollar' arils as influenced by a semi-permeable and an impermeable plastic packaging at a storage temperature of 4°C for 10 days. High quality pomegranate arils packed in semi-

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permeable plastic package and stored at refrigerated conditions prolonged the shelf life (10 days). The high relative humidity within the packages helped to reduce weight loss, maintaining the turgency and texture of the pomegranate arils.

Storage of pomegranate arils under optimal MA have been shown to reduce the risk of enterobacteria, lactic acid bacteria, mesophilic, psychrotrophic, as well as moulds and yeast counts (Sepulveda *et al*. 2000 and Lopez-Rubira *et al*. 2005).

Pomegranate fruits wrapped with shrink film and stored at 8°, 15°and 25°C recorded gradual decrease in acidity at all storage conditions (Nanda *et al.* 2001).

The experimental findings of Sepulveda *et al*. (2001) revealed that minimally processed pomegranate arils (cv. Espanola) packed in BB4 (EVA bags) maintained the physical, chemical and microbiological characters in good condition for a period of 7 days compared to control.

Nanda *et al*. (2001) studied the effect of individual shrink film wrapping with two polyolefin films (BDF-2001 and D-955) and skin coating with a sucrose polyester (SPE) on the shelf life and quality of soft seeded pomegranate cv. Ganesh stored at 8°, 15° and 25℃. Weight loss was greatly reduced in all the packaging treatments whereas, changes in acidity, sugars and vitamin C were lower in wrapped fruits than that of non-wrapped fruits during 12 weeks of storage at 8℃.

The overall quality, anthocyanin content and anti-oxidant activity of minimally processed pomegranate arils of cv. Mollar of Elche (125g) stored under modified atmosphere packaging (MAP) at 5℃ was assessed by Rubira *et al*. (2005). They reported that the polypropylene baskets sealed on the top with bioriented polypropylene (BOPP) was found to be superior in overall quality, anthocyanin content and anti-oxidant activity up to 15days at 5℃.

Palma *et al*. (2009) evaluated the processed seeds of pomegranate cv. Primosole packed in polypropylene trays (150 g each), sealed with 40 µm thick polypropylene film and subsequently stored at 5℃ for 10 days. By the end of storage, pomegranate seeds did not exhibit visible symptoms of decay and no undesirable flavour developed.

Ayhan and Esturk (2009) studied the overall quality and shelf life of minimally processed and modified atmosphere packed ready-to-eat pomegranate arils packed in Polypropylene (PP) trays sealed with bioriented polypropylene (BOPP) film. The findings revealed that the arils could be stored for 18 days with commercially acceptable high quality when stored at 5°C.

The results of experiment conducted by Ayhan and Esturk (2009) revealed that pomegranate arils packed in polypropylene trays, sealed with BOPP film and stored at5°C recorded minimum aerobic mesophilic bacteria of 2.30 to 4.51 log CFU g^{-1} at the end of the storage (18 days).

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Bayram *et al*. (2009) studied the storage performance of pomegranate cv. Hicaznar using different packaging materials and found that streck film wrapped and modified atmosphere packed fruits stored at 6°C and 90% RH showed the highest visual and quality scores upto six months of storage.

Aindongo *et al*. (2014) investigated the effects of Passive-modified atmosphere packaging (MAP) on the quality of minimally processed pomegranate (cv. Bhagwa) arils and aril-sacs stored at 5°C, 10°C, 15°C and 22°C and reported that high rate of respiration and transpiration of arils and aril sacs compared to whole fruit and polyethylene and polymeric film showed greater positive effects in maintaining the quality and extended the shelf life of arils (9 days) and aril-sacs (12 days).

Bhatia *et al*. (2015) investigated the effect of different packing materials (PP, LDPE and KPA) on arils of pomegranate cv. Mridula stored at 5±2°C and 85±5% RH for 15 days. The results revealed that arils packed in PP bags retained better ascorbic acid, antioxidants and anthocyanin and also maintained higher acceptance score (above 6) compared to LDPE and KPA packs upto the 15 days of storage.

Safari *et al*. (2016) studied the effect of packing material (PP, LDPE, HDPE and MP) on pomegranate arils cv. Bhagwa stored under cold storage conditions and room temperature. They observed that arils packed in HDPE 40 per cent microns without perforations had the maximum shelf life upto 22.66 days and also retained highest TSS (14.55°Brix), Brix-acid ratio (46.00%), Total sugars (8.54) and lowest titratable acidity (0.33%).

EFFECT OF STORAGE TEMPERATURES ON QUALITY AND SHELF LIFE OF POMEGRANATE FRUITS

Juven *et al*. (1984) established that modified atmosphere packaged pomegranate arils could last for 3 to 4 weeks at 1°C whereas, it was only 10-14 days at 5°C.

Krishnamurthy (1993) stated that individual shrink wrapped fruits of pomegranate cv. Ganesh when stored at 8°C showed the maximum shelf life of 84 days as compared to those stored at 25°C with and without wrapping (28 and 7 days, respectively).

Gil *et al*. (1996a) reported that MAP stored arils had minimum water loss whereas, unpacked pomegranate arils stored for 7 days at 8°, 4°, and 1°C shrivelled with almost half of the water originally present in the seeds lost during storage.

Gil *et al*. (1996b) stated that no significant change in total anthocyanin content of "Mollar" pomegranate arils stored at 1°C for 7 days whereas, decrease in anthocyanin content was observed when stored at 8°Cand 4°C.

Hess-Pierce and Khader (1997) opined that arils of pomegranate variety Wonderful can be stored upto 16 days at 5°C with 20% CO_2, without changes in the physical and chemical characteristics.

Artes *et al*. (2000a and b) studied the storage behaviour of pomegranate arils at 2°C and 5°C and reported that the best treatment for maintaining red colour of the arils at the end of cold storage was with PPP package at 5°C. The higher levels of decay, mainly due to *Penicillium* sp. were observed in unpackaged treatments at 5°C than those at 2°C.

Hess-Pierce and Kader (2003) found that the seeds of pomegranate cv. Wonderful those had suffered mechanical damage during seed preparation appeared soft and aqueous and were much more susceptible to microbial spoilage. The commercial life of the prepared seeds was 8 days at 10°C and 12 days at 5°C.

Ghatge (2005) reported that, when fruits of pomegranate cv. Ganesh stored at ambient temperature (26-27°C) and low temperature (4-5°C), the shelf life of fruits could be extended up to 6 weeks in low temperature, and up to 4 weeks at ambient temperature storage.

Ergun and Ergun (2009) studied the efficacy of varying concentration of 10 and 20 per cent honey dip treatment on the quality and shelf life of minimally processed pomegranate arils of "Hicaznar" stored at 4°C in loosely closed plastic containers. It was reported that, the total aerobic microbial count was lower.

Caleb *et al*. (2013) investigated the effect of passive modified atmosphere packaging (MAP) and storage temperatures (5°, 10° and 15°C) on post-harvest quality attributes, compositional change in flavour attributes and microbiological quality of minimally processed arils of pomegranate cultivars, 'Acco' and 'Herskawitz'. The results revealed that the post-harvest life of MA-packaged 'Acco' and 'Herskawitz' arils was upto 10 days at 5°C.

The experimental results on influence of low temperature on storage behavior of pomegranate arils of cv. Torsh Syabe Lorestan revealed the lowest microbial count, lowertitratable acidity, total soluble solids, and total anthocyanin even after 14-days of storage (Ghasemnezhad *et al*. 2013).

Oluwafemi *et al*. (2013) evaluated the effect of storage temperatures on arils of two pomegranate cultivars viz., 'Acco' and 'Herskawitz. (75, 100 and 125 g) packed in trays and heat sealed with polylid film and reported that at high storage temperature weight loss and O_2 concentration

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continuously decreased below the critical limit (2%) at 4 days of storage, while at 5°C, this lower limit was not reached. Shelf life of arils was limited to 10, 7 and 3 days at 5°, 10° and 15°C, respectively.

The physico-chemical parameters of pomegranate as influenced by packing and storage conditions were studied by Tabatabaekoloor and Ebrahimpor (2013). The weight loss for EPE-foam and polyethylene-film wrapped fruits were 0.80% and 0.98% at refrigerated storage and 1.51% and 1.84% at ambient conditions, respectively. During the same period, non-wrapped fruits lost 4.97% and 9.50% of weight at ambient and refrigerated conditions, respectively.

Omayma *et al.* (2014) reported that processed pomegranate arils of cv. 'Wonderful' pretreated with ozone for 1, 5 and 10 min. and stored under cold storage at 4°C maintained good quality and appearance for 19 days without microbial visual defects.

The experimental results showed that the weight loss of pomegranate fruits of cv. Wonderful increased with increase in storage temperature and storage period (Arendse *et al.* 2014). Fruits stored at 5°C and 7.5°C recorded weight loss of 27.67 per cent and 45.67 per cent, respectively for 5 months after storage. Colour of fruit and arils decreased whereas, TSS and titratable acidity increased throughout the storage period.

Effect of storage temperature on nutritional composition of arils of three pomegranate cultivars (Arakta, Bahgwa and Ruby) were stored at 1°C, 4°C, and 8°C at 95 per cent RH was studied for 14 days. Nutritional composition of arils was not significantly affected at 1°C and 4°C for 14 days. Temperature did not affect total soluble solids, but increased TA and reduced TSS/TA and nomould growth was observed in arils stored at 1°C after 14 days (Grady *et al.*2014).

CONCLUSION

Packaged pomegranate fruits and arils stored at low temperatures, has retained appreciable nutritional and bio-active compound levels and other quality attributes such as aril colour, taste, flavor and overall acceptability with low microbial count during the entire storage period.

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