

Original Research Article

PROTOCOL FOR SHELF LIFE EXTENSION OF FRESH-CUT POMEGRANATE ARILS (*Punica granatum*, L.)

ABSTRACT

Aims: Pomegranate (*Punica granatum*) is considered as a hard-to-eat fruit, hence used for fresh-cut production. Extension of shelf life of fresh-cut pomegranate arils with quality could facilitate in efficient marketing and transportation resulting in minimizing the post-harvest losses

Study design: Completely Randomized Design

Place and Duration of Study: College of Agriculture, Kerala Agriculture University, February 2022-July 2024.

Methodology: Pomegranate arils were extracted and treated with different pre-treatment solutions viz., 0.5% ascorbic acid, 0.5% citric acid, 1% calcium chloride and 1% calcium ascorbate for 4 minutes. The best pre-treatment solution was selected and arils were packaged in different packaging systems viz., shrink wrapping in 15 μ polyolefin film, vacuum packaging in laminated pouches, MAP with N₂ flushing in laminated pouches, aluminium tray wrapped with cling film and stored under two different storage conditions, after treating with 1% calcium ascorbate.

Results: 1% calcium ascorbate was selected as the best pre-treatment solution and pre-treated arils kept in MAP with N₂ flushing in laminated pouches stored under low temperature condition was found to be the best packaging and storage system. 1% calcium ascorbate treated arils in MAP with N₂ flushing in laminated pouches stored under low temperature condition (10 \pm 5 $^{\circ}$ C) had a shelf life of 6 days with superior physiological, chemical and sensory characters as compared to control (2.00 days). Maximum vitamin C content of 23.02 mg 100g⁻¹ and least phenol content of 214.16 mg 100g⁻¹ were recorded on 6th day of storage.

Conclusion: Pomegranate arils pre-treated with 1% calcium ascorbate for 4 minutes, kept in MAP with N₂ flushing in laminated pouches stored under low temperature condition (10 \pm 5 $^{\circ}$ C) can be considered as a protocol for shelf life extension of pomegranate arils.

Keywords: calcium ascorbate, fresh-cut fruits, MAP, pomegranate arils

1. INTRODUCTION

As the primary source of nutritional components of utmost importance, fruits and vegetables are crucial components of the human diet. Nowadays, consumers are more health and quality conscious and giving more importance to include fruits and vegetables in their diet. Due to a very busy population with their activities and an increase in working women in cities lead to a tendency to demand more convenient food items of fresh, nutritious and easily accessible products, such as fresh-cut produce.

Fresh-cut produce is fruit or vegetable that have been trimmed, peeled and/or cut into a 100% usable form, which is subsequently packaged to offer consumers high nutrition, convenience and flavour while maintaining freshness and quality, therefore known as minimally processed produce [1]. Due to high perishability and seasonality, fruits are not available throughout the year. Fully processed fruits are too expensive for the typical Indian consumers and lack the flavor and wholesomeness of fresh fruit.

Pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits popularly known as Anar. Pomegranate arils have high nutritional value and various health benefits.

They are excellent dietary sources of organic acids, soluble solids, protein, tannin, vitamin C and minerals like calcium, iron, phosphorus and magnesium. Fresh-cut pomegranate arils have high demand due to the difficulty of peeling.

Fresh-cut products have accelerated metabolism due to cutting and other operations that affect their quality. Fresh-cut pomegranate arils are highly perishable and cause significant loss in quality during storage, including loss in colour, firmness and reduction in acidity and vitamin C. On the other hand, they are sensitive to very low temperatures and are severely injured by chilling. These can be reduced by pre-treatments with anti-browning agents, texture improvers etc and by developing appropriate packaging and storage systems; thus facilitating quality sales and transportation. As studies regarding the packaging of fresh-cut pomegranate arils are lacking, an experiment was undertaken with the objective to standardize packaging and storage systems for shelf life extension of fresh-cut pomegranate arils.

2. MATERIAL AND METHODS

Good quality, ripe pomegranate fruits (cv. Kaveri) of uniform maturity, weight and colour were procured from VFPC outlet, Thiruvananthapuram, sanitized by ozonation (2 ppm). Experiments were carried out in two parts viz., evaluation of pre-treatments and development of packaging and storage system.

Pomegranate arils (100% usable form) were extracted from the sanitized fruits and treated with four different solutions viz., 0.5% ascorbic acid, 0.5% citric acid, 1% calcium chloride and 1% calcium ascorbate for 4 minutes, air-dried and were kept in a recasheath bowl wrapped with cling film along with untreated arils (control), under refrigeration ($5 \pm 2^\circ\text{C}$) till the end of shelf life so as to form 5 treatments with 4 replications in Completely Randomised Design. The best pre-treatment solution was selected based on superior physiological (PLW, percent leakage), chemical (vitamin C, phenol) and sensory parameters of arils.

In the second part, fresh-cut pomegranate arils pre-treated with the best solution were subjected to five different packaging systems viz., shrink wrapping in 15 μ polyolefin film, vacuum packaging in laminated pouches, Modified Atmospheric Packaging (MAP) with N_2 flushing in laminated pouches, aluminium tray wrapped with cling film and open storage in paper plate (control) and stored under two different conditions viz., low temperature storage ($10 \pm 5^\circ\text{C}$) and refrigerated ($5 \pm 2^\circ\text{C}$) storage for 10 treatments with 2 replications in a Completely Randomised Design.

Physiological, chemical and sensory parameters of arils were recorded at the time of storage till the end of shelf-life. Physiological parameters include physiological loss in weight and percent leakage. Chemical parameters such as acidity [2], vitamin C [2], phenol [3] were recorded initially and till the end of shelf-life. Sensory parameters like color, taste, appearance, flavour and texture of pomegranate arils were reevaluated initially, one and two days after storage by conducting organoleptic evaluation with a semi-trained panel of 30 members [4]. Data recorded from the experiments were statistically analyzed using GRAPES [5].

Based on superior physiological, chemical and sensory parameters of arils, a protocol was standardized comprising of best packaging and storage system capable of quality retention of fresh-cut pomegranate arils was selected.

3. RESULTS AND DISCUSSION

3.1. EFFECT OF PRE-TREATMENTS

1% calcium ascorbate treated fresh-cut pomegranate arils resulted in better physiological parameters as compared to other treatments. The Physiological loss in weight (PLW) and percent leakage of fresh-cut pomegranate arils showed an increasing trend during storage irrespective of the pre-treatments (Table 1 & 2). Pre-treated arils had low PLW and percent leakage as compared to untreated arils (control). Pomegranate arils treated with 1% calcium ascorbate had maximum shelf life of 5.00 days followed by arils treated with 1% calcium chloride and 0.5% ascorbic acid (4.00 days); whereas untreated and citric acid treated arils had the least shelf life of 3.00 days. When treated with calcium salts, the shelf life of fresh-cut pomegranate arils was extended to 2 days as compared to other treatments. Due to exposure of internal tissues and lack of skin or cuticle, fresh-cut fruits are highly susceptible to weight loss [6]. After 3rd day of storage, minimum PLW (1.15%) was recorded for 0.5% ascorbic acid treated arils followed by 1% calcium ascorbate treated arils (1.05%), whereas arils treated with 0.5% citric acid (5.00%) and untreated arils (4.20%) had highest PLW. Untreated arils had the least shelf life of 3.00 days with maximum PLW (4.20%) and percent leakage (73.50%). All the arils except those treated with 1% calcium ascorbate were discarded due to spoilage after 4th day of storage. Pomegranate arils treated with 1% calcium ascorbate had minimum PLW (1.7%) and percent leakage (51.68%) on 5.00 days after storage. Least percent leakage of pomegranate arils was due to high membrane integrity [7].

Table 1. Effect of pre-treatments on physiological loss in weight (PLW) of fresh-cut pomegranate arils

Treatments	PLW (%)
------------	---------

	Days after storage (D)			
	1	3	4	5
0.5% Ascorbic acid	0.80	1.15 ^c	4.20 ^a	*
0.5% Citric acid	0.35	5.00 ^a	*	*
1% Calcium chloride	0.85	2.90 ^b	3.62	*
1% Calcium ascorbate	0.35	1.05 ^c	1.40 ^b	1.70
Control	1.55	4.20 ^{ab}	*	*
SE±(m)	0.342	0.571	0.611	
CD(0.05)	NS	1.720	2.114	

Table 2. Effect of pre-treatments on percent leakage of fresh-cut pomegranate arils

Treatments	Percent leakage (%)			
	Days after storage (D)			
	At storage	3	4	5
0.5% Ascorbic acid	25.55	39.69 ^d	71.90 ^a	*
0.5% Citric acid	25.62	54.63 ^b	*	*
1% Calcium chloride	25.45	46.06 ^c	46.65 ^b	*
1% Calcium ascorbate	25.69	33.71 ^e	39.17 ^c	51.68
Control	25.44	73.50 ^a	*	*
SE±(m)	0.127	1.582	1.359	
CD (0.05)	NS	4.769	4.346	

The vitamin C content of pre-treated fresh-cut pomegranate arils decreased during storage period. Similar result was observed by [8]. The decrease in vitamin C content of fresh-cut produce during storage might be due to the oxidation of ascorbic acid to dehydroascorbic acid, followed by hydrolysis of the latter to 2,3-diketogulonic acid [9]. The maximum vitamin C content (35.11 mg 100g⁻¹) was recorded in fresh-cut pomegranate aril treated with 1%

calcium ascorbate which was statistically on par with arils treated with 0.5% ascorbic acid; whereas the least vitamin C content was observed in untreated arils after 3 days of storage. The least vitamin C content was shown by arils treated with 1% calcium chloride (23.37 mg 100g⁻¹) followed by arils treated with 0.5% ascorbic acid (23.72 mg 100g⁻¹) after 4 days of storage. 1% calcium ascorbate treated pomegranate arils were retained up to 5 days after storage with a vitamin C content of 23.26 mg 100g⁻¹ (Fig.1).

Phenol content of pre-treated arils increased during storage and the highest phenol content was recorded for untreated arils (214.98 mg 100g⁻¹); whereas 1% calcium ascorbate treated arils had the least phenol content of 191.54 mg 100g⁻¹ after 3 days of storage. After 4 days of storage, the pomegranate arils treated with 1% calcium ascorbate recorded the least phenol content (196.93 mg 100g⁻¹) and the highest phenol content (210.26 mg 100g⁻¹) was recorded in pomegranate arils treated with 1% calcium chloride (Fig.2). Low phenol content is considered as an indication of reduced enzymatic browning and superior physical parameters like appearance and colour. This was in accordance with findings of [10] who had reported that enzyme activities responsible for browning with improved consumer acceptance were reduced by treating with calcium ascorbate in brinjal.

Pre-treated pomegranate arils recorded the highest scores for sensory parameters compared to untreated arils during storage. Among treatments, pomegranate arils treated with 1% calcium ascorbate showed the highest mean scores for colour, texture, appearance, taste and overall acceptability on first and third days of storage. This is in accordance with the results of [11] who had reported a higher sensory rating for calcium ascorbate treated apple slices. Calcium ascorbate helps in stabilization of membranes systems and formation of calcium pectates, which results in increased rigidity of the middle lamella and cell walls. This also retards polygalacturonase (PG) activity and thereby preventing browning [12].

Based on superior physiological, chemical and sensory parameters, 1% calcium ascorbate was selected as the best pre-treatment solution. In the second part, 1% calcium ascorbate treated fresh-cut pomegranate arils were subjected to different packaging systems and stored under two different conditions to develop efficient packaging and storage systems for arils.

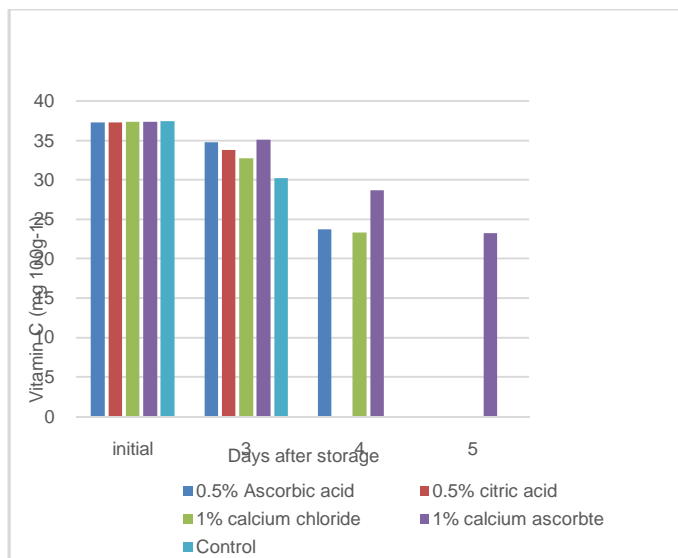


Fig 1. Effect of pre-treatments on vitamin C of fresh-cut pomegranate arils

Fig. 3. Effect of packaging and storage on PLW of fresh-cut pomegranate arils

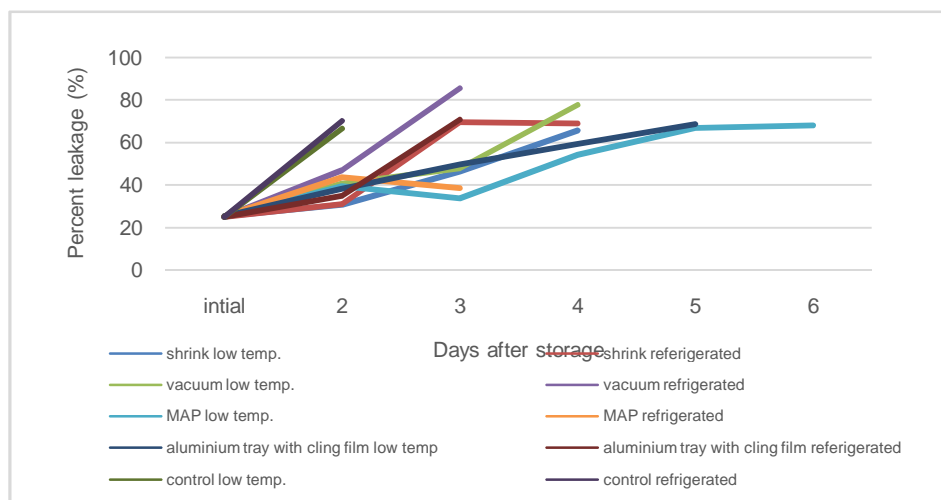


Fig. 4. Effect of packaging and storage on percent leakage of fresh-cut pomegranate arils

During storage, the vitamin C content of fresh-cut pomegranate arils can degrade, and the packaging material, storage conditions and their interaction can influence the rate of degradation. At the time of storage, fresh-cut pomegranate arils had a vitamin C content of $30.00 \text{ mg}100 \text{ g}^{-1}$ and it reduced to $23.02 \text{ mg}100 \text{ g}^{-1}$ at the end of shelf life. The rate of degradation was low for arils in MAP with N_2 flushing in laminated pouches under low temperature storage and highest for unpackaged arils. The same trend was followed on 2nd, 3rd and 4th day after storage. Fresh-cut pomegranate arils pre-treated with 1% calcium ascorbate recorded the maximum vitamin C content ($24.34 \text{ mg}100 \text{ g}^{-1}$) when kept in MAP with N_2 flushing in laminated pouches under low temperature storage followed by arils in aluminium tray wrapped with cling film ($18.87 \text{ mg}100 \text{ g}^{-1}$) after 5th day of storage (Fig. 5). Vitamin C content of packaged fresh-cut pomegranate arils fluctuated during the period of storage [6]. Arils in MAP with N_2 flushing in laminated pouches stored under low temperature condition were retained upto 6th day after storage with a vitamin C of $23.02 \text{ mg}100 \text{ g}^{-1}$.

Phenol content of packaged pomegranate arils was also increased with the storage period (Fig. 6). Least phenol content of $186.28 \text{ mg}100 \text{ g}^{-1}$ was recorded for arils in aluminium tray wrapped with cling film during low temperature storage followed by vacuum packaged arils stored under low temperature ($186.82 \text{ mg}100 \text{ g}^{-1}$) and refrigerated conditions ($187.36 \text{ mg}100 \text{ g}^{-1}$). The arils without any package recorded the highest phenol of $215.92 \text{ mg}100 \text{ g}^{-1}$ during refrigerated storage followed by those arils stored under low temperature condition ($214.98 \text{ mg}100 \text{ g}^{-1}$) on 2nd day after storage. Minimum phenol content of $206.90 \text{ mg}100 \text{ g}^{-1}$ was recorded for arils in MAP with N_2 flushing in laminated pouches under low temperature storage after 5th day of storage; whereas, the highest phenol content was noticed for arils in aluminium tray wrapped with cling film during low temperature storage ($212.41 \text{ mg}100 \text{ g}^{-1}$). According to [14], dipping of fresh-cut produce in calcium ascorbate solutions had a positive effect on quality retention.

These sensory parameters of fresh-cut pomegranate arils were significantly influenced by packaging and storage systems. Pre-treated pomegranate arils in MAP with N_2 flushing in laminated pouches stored under low temperature condition recorded the highest scores for all sensory parameters on 1st and 2nd day after storage. This result is confirmed by [15] in pomegranate arils. MAP could result in maintaining a better structure, lower tissue damage and improved qualities of arils during storage. [16] demonstrated that the application of active Modified Atmospheric Packaging combined with ascorbic acid coating, maintained the sensory attributes and extended the shelf life of fresh-cut pomegranate arils by approximately 30%.

Based on effectiveness of packaging materials and storage conditions in maintaining superior physiological, chemical and sensory parameters and shelf-life of fresh-cut pomegranate arils, 1% calcium ascorbate treated arils kept in MAP with N_2 flushing in laminated pouches under low temperature storage was found to be the best treatment.

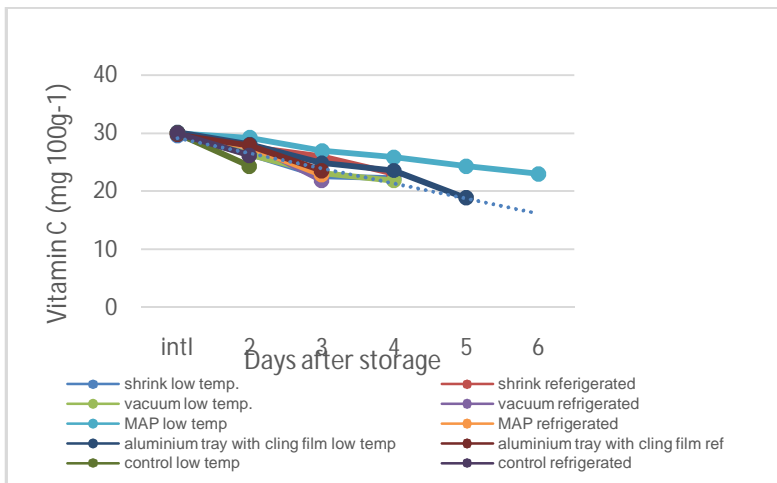


Fig. 5. Effect of packaging and storage on vitamin C of fresh-cut pomegranate arils

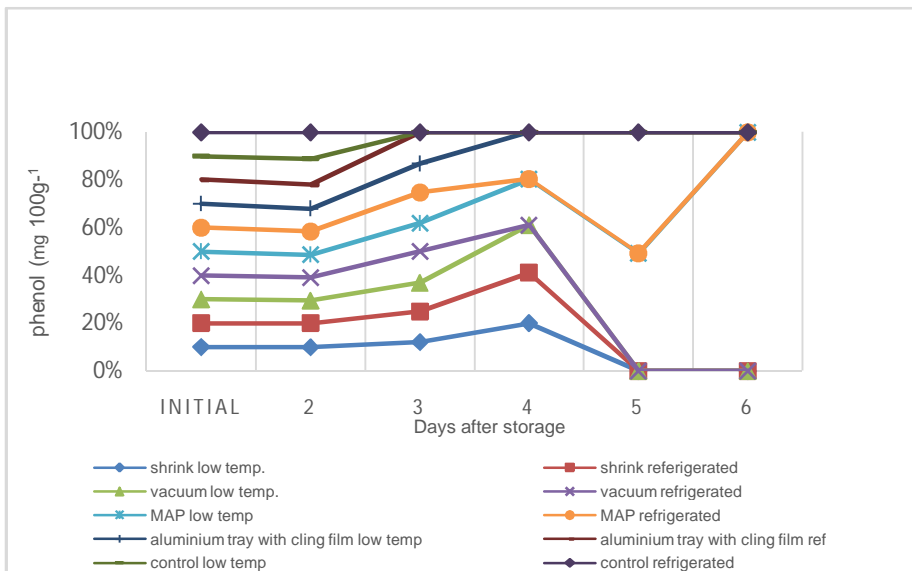


Fig. 6. Effect of packaging and storage on phenol of fresh-cut pomegranate arils

4. CONCLUSION

1% calcium ascorbate was selected as the best pre-treatment solution for fresh-cut pomegranate arils with superior physiological, chemical and sensory parameters. The physiological loss in weight, percent leakage, ascorbic acid and phenol content of fresh-cut pomegranate arils were influenced by packaging materials, storage conditions and their interaction. Arils pre-treated with 1% calcium ascorbate and kept in MAP with N₂ flushing in laminated pouches under low temperature (10±5°C) storage proved to be the best packaging and storage systems with a shelf-life of 6 days as compared to 2 days for unpackaged arils by retaining fresh-like characters with minimum loss in weight, percent leakage, phenol and maximum vitamin C content. As they alter the surrounding atmosphere of arils and help in preventing enzymatic browning and improve texture.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative ai technologies such as large language models (chatgpt, copilot, etc) and text-to-image generators have been used during writing or editing of this manuscript.

REFERENCES

1. IFPA, The International Freshcut Produce Association. IFPA homepage (online). Fresh cut facts. 2004. <http://www.freshcuts.org>.
2. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Education; 1986.

- 3.Sadasivam S. Biochemical methods. New age international; 1996.
- 4.Amerine MA, Pangborn RM, Roessler EB. Principles of Sensory Evaluation of Food. Academic Press. New York/ London.1965.
- 5.Gopinath PP, Parsad R, Joseph B, Adarsh VS. GrapesAgri1: collection of shiny apps for data analysis inagriculture. Journal of OpenSource Software. 2021 Jul 18;6(63):3437.
- 6.O'Grady L, Sigge G, Caleb OJ, Opara UL. Effects of storage temperature and duration on chemical properties, proximate composition and selected bioactive components of pomegranate (*Punica granatum L.*) arils. 2014; LWT.57: 508–515.
- 7.Amith P K. . Protocol development for fresh- cutfruitsandfruitmixpreparation.M.Sc. (Hort) thesis, KeralaAgricultural University, Thrissur.2012;125.
- 8.Sally K B. Studies on packaging and storage of minimally processed jackfruit(*ArtocarpusheterophyllusL.*)bulbs. M.Tech.(Ag.Engg.)thesis,Universityof Agricultural SciencesGKVK,Bangalore.2011; 183.
- 9.DewantoV,WuX,AdomKK,LiuRH.Thermalprocessingenhancesthenutritionalvalueoftomatoesbyincreasingtotal antioxidantactivity.*J. Agric. Food Chem.*2002;50(10): 3010-3014.
- 10.Barbagallo RN,Chisari M, Caputa G.Effects of calcium citrate andascorbateas inhibitorsofbrowningandsofteninginminimallyprocessed „Birgah”eggplants.*PostharvestBiol. Technol.*2012; 73:107-114.
- 11.Aguayo E, Requejo-Jackman C, Stanley R. Woolf A. Effects of calcium ascorbate treatments and storage atmosphere on antioxidant activity and quality of fresh-cut apple slices. *Postharvest bio. Technolo.* 2010; 57(1): 52-60.
12. Poovaiah BW. Role of Ca in prolonging the storage life of fruits and vegetables. *Food Technol.*1986;40: 86–89.
- 13.RaiDR,Paul S.Predictionoftransientstatein-packrespiratorybehavior of button mushroom (*Agaricus bisporus*) under modified atmospheric packaging. *J. Food Sci. and Technol.* 2007;44:32-35.
- 14.Gonzalez-Aguilar G A, Ayala-Zavala J, Olivas G, Alvarez-Parrilla E. Preserving quality of fresh-cut products using safe technologies. *J. VerbrauchLebensm.* 2010;5(1): 65– 72.
- 15.Rokalla P, Inbaraj BS, Dikkala PK, Sridhar K, Dasi DS, et al. Active-modified atmosphere packaging of ready-to-eat pomegranate (*Punica granatum L.*) arils at ambient temperature for extending shelf-life. *Agriculture.*2022; 12(2): 155.
- 16.Moradinezhad F, Ansarifard E, Mohammadian Moghaddam M. Extending the shelf life and maintaining quality of minimally-processed pomegranate arils using ascorbic acid coating and modified atmosphere packaging. *J. Food Meas. Charact.* 2020; 14:3445–3454.