Original Research Article

EFFECT OF DIFFERENT CHEMICAL TREATMENTS AND PACKAGING SYSTEMS ON QUALITY CHARACTERISTICS OF FRESH-CUT POMEGRANATE ARILS (*Punica granatum, L.*)

ABSTRACT

Aims: Pomegranate (*Punica granatum*) is considered aschallenging to consume due to its hardstructure, hence used for fresh-cut production. Extending the shelf life of fresh-cut pomegranate arils would improve their marketability, transport efficiency, and reduce post-harvest losses.

Study design: Completely Randomized Design by using GRAPES (General R based Analysis Platform Empowered by Statistics)
Place and Duration of Study: College of Agriculture, Kerala AgriculturalUniversity,February 2022-July 2024.
Methodology: Pomegranate arils wereextracted and treated with different pre-treatment solutions *viz.*, 0.5% ascorbic acid, 0.5% citric acid, 1%calciumchlorideand1%calciumascorbatefor4minutes.Thebest pre-treatment solution was selected andarilswerepackaged in different packaging systems *viz.*, shrink wrapping in 15µpolyolefin film, vacuum packaging in laminated pouches, MAP with N_2flushing in laminatedpouches,aluminiumtraywrappedwithclingfilmandstoredundertwodifferentstorageconditions, after treating with 1%calciumascorbate.

Results:1% calciumascorbate was selected as the best pre-treatment solution and pre-treated arilskept in MAP with N_2flushing in laminatedpouches stored under low temperature condition was found to be the best packaging and storage system.1% calciumascorbate treated arils in MAP with N_2flushing in laminatedpouches stored under low temperature condition (10±5^{o}C)had a shelf life of 6 days with superior physiological (PLW, percent leakage), chemical (acidity, vitamin C, phenol) and sensory characters (color, flavour, texture, appearance, taste and overall acceptability) as compared to control (2.00 days). Maximum vitamin C content of 23.02mg100g^{-1} and least phenol content of 214.16mg100g^{-1} were recorded on 6th day of storage.

Conclusion: Pomegranate arilspre-treated with 1% calciumascorbate for 4 minutes, kept in MAP with N_2flushing in laminatedpouches stored under low temperature condition (10±5^{o}C) can be considered as a protocol for shelf life extension of pomegranatearils.

Keywords: calciumascorbate, fresh-cut fruits,MAP, pomegranatearils

1. INTRODUCTION

As the primary source of nutritionalcomponents of utmost importance, fruits and vegetablesarecrucialcomponentsofthehuman diet. Nowadays, consumers are morehealthandqualityconsciousandgivingmoreimportancetoincludefruitsandvegetablesintheirdiet.Duetoaverybusypopulationwiththeir activities and an increase in workingwomenincitiesleadstoatendencytodemandmoreconvenientfooditemsoffresh,nutritiousandeasilyaccessibleproducts, suchas fresh-cut produce.

Fresh-cut produce is fruit or vegetable thathave been trimmed, peeled and/or cut into a100%usableform,whichissubsequentlypackagedtoofferconsumershighnutrition, convenience and flavour while maintainingfreshnessandquality,thereforeknownasminimally processed produce [1].Duetohighperishabilityandseasonality,fruits are not available throughout the year.Fully processed fruits are too expensive forthe typical Indian consumers and lack theflavorandwholesomenessoffreshfruit.

Pomegranate(*Punicagranatum*L.)isoneoftheoldestknownediblefruitspopularly known as Anar. Pomegranate arilshavehighnutritionalvalueandvarioushealthbenefits. Theyareexcellentdietarysourcesoforganicacids,solublesolids,protein, tannin, vitamin C and minerals likecalcium, iron, phosphorus and magnesium.Fresh-cutpomegranatearilshavehighdemandduetothedifficultyofpeeling.

Fresh-cutproductshaveacceleratedmetabolismduetocuttingandotheroperations that affect their quality. Fresh-cutpomegranate arils are highly perishable andcausesignificantlossinqualityduringstorage,including lossincolour,firmnessand reduction in acidity and vitamin C. Onthe other hand, they are sensitive to very lowtemperaturesandareseverelyinjuredbychilling.Thesecanbereducedbypre-treatmentswithanti-browningagents,textureimprovers etc and by developing appropriatepackagingandstoragesystems;thusfacilitatingqualitysalesandtransportation. Asstudiesregardingthepackagingoffresh-cut pomegranate arils are lacking, anexperimentwasundertakenwiththeobjectivetostandardizepackagingandstorage systems for shelf life extension offresh-cutpomegranate arils.

2. MATERIAL AND METHODS

Good quality, ripe pomegranate fruits (*cv*.Kaveri) ofuniformmaturity,weightandcolourwere procuredfromVFPCK outlet, Thiruvananthapuram and sanitized byozonization(2ppm).Experimentswere carried out in two parts *viz*., evaluation ofpre-treatmentsanddevelopmentofpackaging and storage system.

In the first part, pomegranate fruits were made into 100%usableform by extracting arils from the sanitized fruits andpre-treated with four distinctsolutions, namely, 0.5% ascorbic acid, 0.5% citric acid, 1% calcium chloride and 1% calcium ascorbate for 4 minutes,air dried and werekeptinarecasheathbowlswrapped withclingfilmalongwithuntreatedarils(control),underrefrigeration(5±2^{o}C) till the end of shelf life soastoform 5treatmentswith4replicationsinCompletelyRandomised Design by using GRAPES [5]. Thebestpre-treatmentsolutionwasselectedbasedon superior physiological (PLW, percent leakage), chemical (vitamin C, phenol) and sensory parameters of arils.

Inthesecondpart,fresh-cut pomegranate arils treated withthe best pre-treatmentsolution selected from the first part were subjected to five differentpackaging systems *viz*., shrink wrappingin15µpolyolefinfilm,vacuumpackaging in laminated pouches, Modified Atmospheric Packaging (MAP)with nitrogen (N_2)flushing in laminated pouches, aluminium tray wrapped with cling film andopen storage in paper plate (control) and stored under two different conditions *viz*., low temperature(10±5°C) andrefrigerated(5±2°C)storagetoform10treatmentswith2replicationsinaCompletelyRandomised Design (General R based Analysis Platform Empowered by Statistics) [5].

Physiological, chemicaland sensory parameters of arils wererecordedatthetimeofstoragetilltheendofshelf-life.Physiological parameters include physiological loss in weight (calculated as cumilative weight loss by noting the weight of produce daily and deducted from the initial weight recorded at the time of storage and expressed as percentage) and percent leakage. Chemical parameters such as acidity [2], vitamin C [2], phenol [3]were recorded initially and till the end of shelf-life. Sensoryparameterslikecolor,taste,appearance,flavorandtextureofpomegranatearilswereevaluated initially, one and two days afterstoragebyconductingorganoleptice valuation with a semi-trained panel of 30members[4]. Datarecordedfromtheexperimentswerestatisticallyanalyzedusing GRAPES [5].

Based on superior physiological, chemical and sensory parameters of arils, a protocol was standardized comprising ofbestpackagingandstoragesystemcapableof qualityretentionoffresh-cutpomegranatearils.

3. RESULTS AND DISCUSSION

3.1. EFFECT OF PRE-TREATMENTS

1% calcium ascorbate treated fresh-cutpomegranatearilsresultedinbetterphysiological parameters as compared to othertreatments. The Physiological loss in weight(PLW) and percentleakageoffresh-cutpomegranatearils showed an increasing trend during storage irrespective of thepre-treatments (Table1 & 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. Duetoexposureof internaltissuesandlackofskinorcuticle,fresh-cutfruitsarehighlysusceptibletoweightloss[6]. After 3rd day of storage, minimum PLW (1.15%) was recorded for 0.5% ascorbic acid treated arils followed by 1%calciumascorbate 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 3.00dayswithmaximumPLW(4.20%)andpercentleakage(73.50%). All the arils except those treated with 1% calcium ascorbate were discarded due to spoilage after 4th day of storage.Ascorbic acid acts as an anti-browning agent, citric acid is an acidulant and calcium chloride acts as a firming agent.Calcium ascorbate has both the properties of firming and anti-browning. Therefore, calcium ascorbate treated pomegranate arils

were found to be the best for maintaining the quality and extending shelf life compared to arils treated with other pre-treatment solutions viz., ascorbic acid, citric acidand calcium chloride.Pomegranate arils treated with 1%calciumascorbatehadminimum PLW (1.7%) andpercentleakage(51.68%) on 5.00 days after storage. The principal factor responsible for weight loss has been determined to be water loss through transpiration and respiration [7] and the leastpercentleakagewasduetohigh membraneintegrity[8].

Table1.Effectofpre-treatmentsonphysiologicallossinweight(PLW)offresh- cutpomegranatearils

Pre-treatments	PLW(%)			
	Daysafterstorage(D)			
	1	3	4	5
0.5%Ascorbicacid	0.80	1.15^{c}	4.20^{a}	*
0.5%Citricacid	0.35	5.00^{a}	*	*
1%Calciumchloride	0.85	2.90^{b}	3.62	*
1%Calciumascorbate	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	

Table2.Effectofpre-treatmentsonpercent leakage offresh-cutpomegranatearils

Pre-treatments	Percent leakage (%)			
	Days after storage (D)			
	At storage (0)	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	

ThevitaminCcontentofpre-treatedfresh-cutpomegranatearilsdecreased duringstorageperiod.Similarresultwasobservedby[9].Thedecrease in vitamin C content of fresh-cutproduce during storage might be due to theoxidationofascorbicacidtodehydroascorbicacid,followedbyhydrolysis of the latter to 2,3-diketogulonicacid [10]. The maximumvitaminCcontent(35.11mg100g^{-1})wasrecordedinfresh-cutpomegranatearilstreated with 1% calcium ascorbate whichwasstatisticallyonparwitharilstreated with 0.5% ascorbic acid; whereas the leastvitaminCcontentwasobservedinuntreatedarils after 3 days of storage. The least vitamin C content was shown by arils treated with 1% calcium chloride (23.37 mg100g^{-1}) followed by arils treated with 0.5% ascorbic acid (23.72 mg 100g^{-1}) after 4 days of storage. 1% calciumascorbatetreatedpomegranatearilswere retainedupto 5 days after storage with a vitamin Ccontent of 23.26 mg100g^{-1} (Fig.1).

Phenolcontentofpre-treatedarilsincreasedduringstorageandthehighest phenol content was recorded for untreatedarils(214.98mg100g^{-1});whereas1%calcium ascorbate treated arils had the leastphenol content of 191.54 mg 100g^{-1} after 3days 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 [11]who had reportedthat enzyme activities responsible for browning with improved consumer acceptance were reduced by treating with calcium ascorbate in brinjal.

Pre-treatedpomegranatearilsrecordedthehighestscoresforsensoryparameterscomparedtountreatedarilsduringstorage .Amongtreatments,pomegranate arils treated with 1% calciumascorbateshowedthehighestmeanscoresforcolour, texture, appearance, taste and overallacceptabilityonfirstandthirddaysofstorage.Thisisinaccordancewiththeresults of [12] who had reported ahigher sensory rating for calcium ascorbatetreated apple slices. Calcium ascorbate helpsinstabilizationofmembranesystemsandformation of calcium pectates, which resultsin increased rigidity of the middle lamellaandcellwalls.Thisalsoretardspolygalacturonase (PG) activity and therebypreventingbrowning[13].

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.

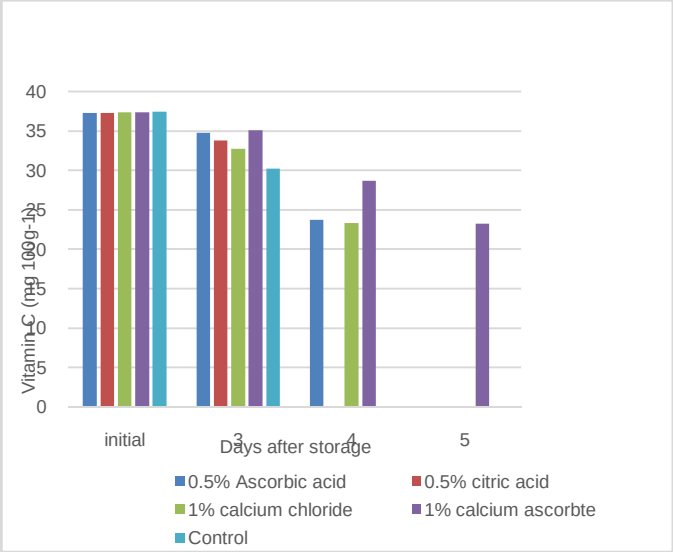

Fig 1. Effect of pre-treatments on vitamin C of fresh-cut pomegranatearils

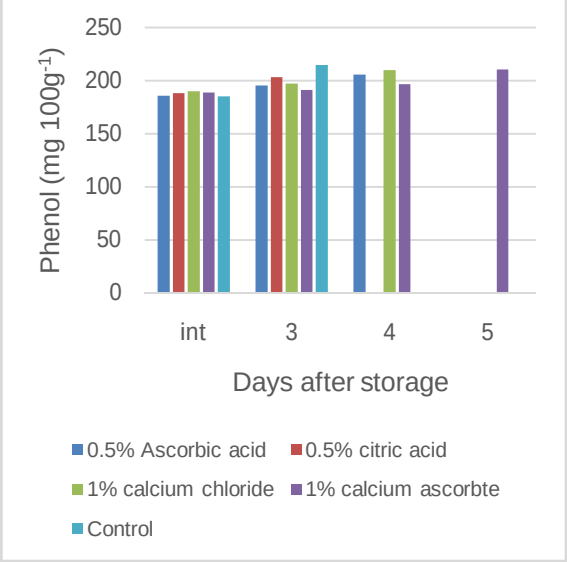

Fig 2. Effect of pre-treatments on phenol of fresh-cut pomegranatearils

3.2. EFFECT OF PACKAGING AND STORAGE SYSTEMS

Physiologicallossinweight(PLW)offresh-cutpomegranatearils were significantlyinfluencedbypackagingsystemsandstorageconditions. The physiological loss in weightwasincreasedduringtheperiodofstoragefor all packaged arils, indicating deterioration at the end of shelf life. The lowest PLW (0%) was recorded for shrink wrapped pomegranate arils under low temperature storage and the highest loss in weight (2.70%) was observed for arils without any packageunder refrigerated storage(Fig. 3). After 2nd day of storage, arils in MAP with N_2 flushing in laminated pouches under low temperature storage recorded the least PLW of 1.30% with minimum percent leakage of 39.47%. Unpackaged arilsrecorded the highest PLW of 5.10% during refrigerated storage with maximum percent leakage of 70.26%.This result is in conformity with the findings of [14]who had observed highest PLW for unpackaged fresh-cut produce during storage. All the arils except those in MAP with N_2 flushing in laminated pouches and arils in aluminium tray wrapped with cling film stored under low temperature storage were discarded due to spoilage after 4 days of storage. Arils in MAP with N_2 flushing in laminated pouches under low temperature storage were retained upto 6 days with a PLW of 3.88% and percent leakage of68.15% (Fig. 4).

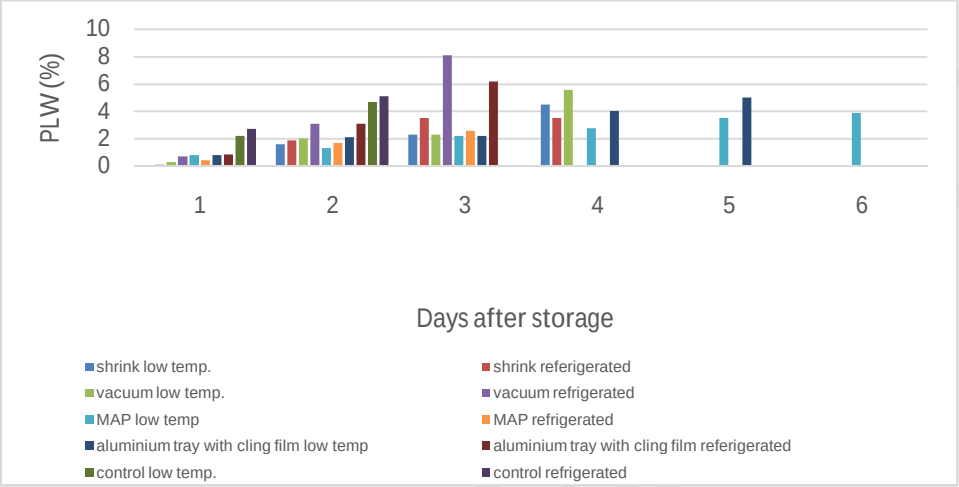

Fig. 3. Effect of packaging and storage on PLW of fresh-cut pomegranate arils

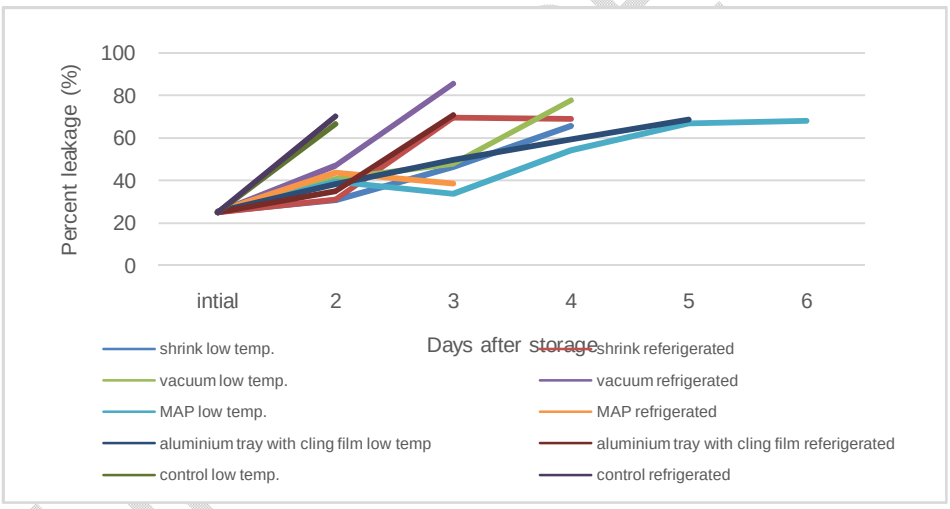

Fig. 4. Effect of packaging and storageon percent leakage of fresh-cut pomegranate arils

Effect of packaging and storage on vitamin Ccontent of fresh-cut pomegranate arils was found to be significant. During storage, the vitamin C content of packaged fresh-cut pomegranate arils can be degraded and the rate of degradation
influenced by the packaging systems, storage conditions and their interaction. At the time of storage, fresh-cut pomegranate arilshad a vitamin C content of 30.00 mg100 g^{-1} and it wasreduced to 23.02 mg100 g^{-1} at the end of shelf life (6 days). The rate of degradation was low for arils in MAPwithN_2flushinginlaminated pouches under low temperaturestorage(10±5°C) and highest for unpackaged arils. The same trend was followed on 2nd, 3rd and 4th day after

storage. Fresh-cutpomegranatearilspre-treatedwith1%calcium ascorbate recorded the maximumvitamin C content (24.34 mg100g^{-1}) whenkeptinMAPwithN_2flushinginlaminated pouches under low temperaturestorage followed by arils in aluminium traywrapped with cling film (18.87 mg 100g^{-1})after 5th day of storage (Fig. 5). Vitamin Ccontent of packaged fresh-cut pomegranatearils fluctuated during the period of storage[6].The declining trend of vitamin C in fresh-cut arils is attributed to water loss, cell wall damage, temperature, humidity, storage and packaging environment[15].Arils in MAP withN_2flushing inlaminatedpouchesstoredunderlowtemperatureconditionwereretained upto 6th day after storage with avitaminC of 23.02mg100g^{-1}.The decrease in vitamin C content of fresh-cut pomegranate arils may be due to the metabolic changes in the arils by the use of organic acids duringrespiration [16].

Phenol content of packagedpomegranatearilswasalsoincreasedwith the storage period (Fig. 6).Least phenol content of 186.28 mg 100g^{-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(186.82mg 100g^{-1}) and refrigerated conditions (187.36 mg100g^{-1}). The arils without any package recorded the highest phenolcontent of 215.92 mg100g^{-1} during refrigerated storage followed by those arils stored under low temperature condition (214.98 mg100g-^{1}) on 2nd day after storage. Minimum phenol contentof 206.90mg100g^{-1}wasrecordedforarilsin MAP with N_2flushing in laminated pouchesunderlowtemperaturestorageafter5thdayofstorage; whereas, the highest phenol contentwas noticedfor arils in aluminium tray wrapped with cling filmduring lowtemperaturestorage(212.41 mg100g^{-1}). According to [17],dippingoffresh-cutproduceincalcium ascorbate solutions had a positiveeffect on quality retention. Stress response to wounding during the preparation of fresh-cut produce (production of stress alleviating phyto-chemicals) causes an increase in the phenol content [15].

Thesensoryparametersoffresh-cutpomegranatearilswere significantly influenced by packagingandstoragesystems.Pre-treatedpomegranate arils in MAP with N_2flushinginlaminatedpouchesstoredunderlowtemperature condition recorded the highestscores for all sensory parameters on 1st and2nddayafterstorage.Thisresultisconfirmedby[16]inpomegranatearils,MAPcouldresultinmaintainingabetterstructure , lower tissue damage and improvedqualitiesofarils duringstorage. [17] 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 packagingmaterialsandstorageconditions in maintainingsuperiorphysiological, chemical and sensory parameters and shelf-life of fresh-cut pomegranate arils, 1% calcium ascorbatetreated arils kept in MAP with N_2flushing inlaminatedpouchesunderlowtemperaturestoragewasfoundtobethebesttreatment.

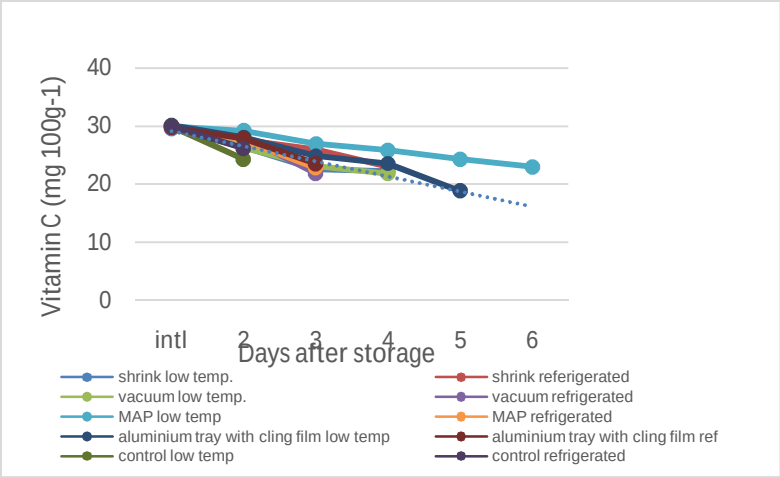

Fig. 5. Effect of packaging and storageon vitamin C of fresh-cut pomegranatearils

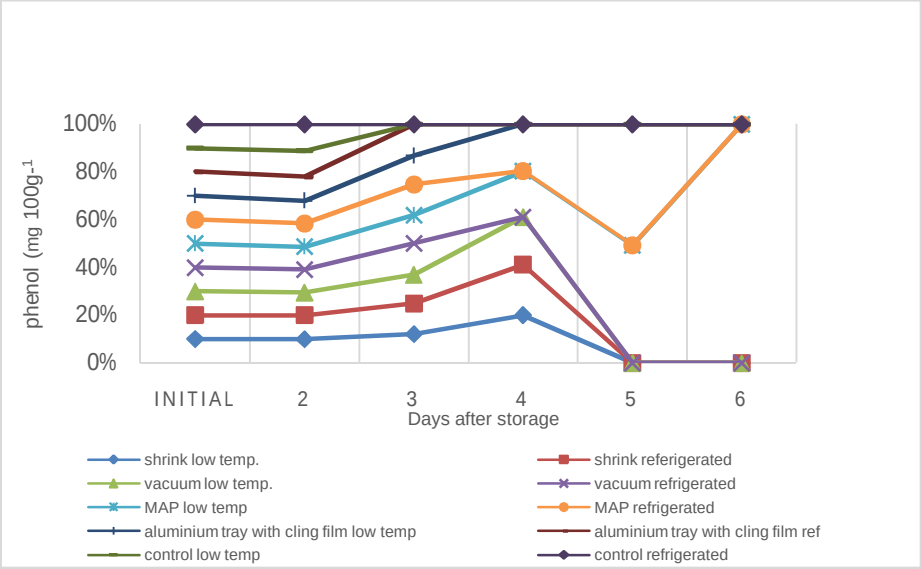

Fig. 6. Effect of packaging and storage on phenol of fresh-cutpomegranate arils

4. CONCLUSION

1% calcium ascorbatewasselectedasthebestpre-treatmentsolution for fresh-cut pomegranate arils withsuperiorphysiological, chemicaland sensory parameters. The physiological lossinweight,percentleakage,vitamin C andphenolcontentoffresh-cutpomegranate arils were influenced bypackaging systems, storage conditions and their interaction. Arils pre-treated with1%calciumascorbateandkept in$MAP with N_2$flushinginlaminated pouches under lowtemperature(10±5^{o}C)storageprovedtobethebestpackagingand storage systems with a shelf-lifeof6daysascomparedto2daysfor unpackagedarilsbyretainingfreshlikecharacterswithminimumlossinweight,percentleakage,phenolandmaximumvitamin C content. As they alter the surrounding atmosphere of arils and helps in preventingenzymaticbrowningandimprovestexture.

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.

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