Original Research Article

PROTOCOLFORSHELFLIFE EXTENSIONOFFRESH-CUTPOMEGRANATEARILS (*Punica granatum, L.*)

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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 AgricultureUniversity,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, chemical and sensory characters 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.

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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.Duetoaverybusypopulation withtheir 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.

Pomegranateal(*Punicagranatum*L.)isoneoftheoldestknownediblefruitspopularly known as Pomegranate arilshavehighnutritionalvalueandvarioushealthbe

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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, sanitized byozonization(2ppm).Experimentswere carried out in two parts *viz*., evaluation ofpre-treatmentsanddevelopmentofpackaging and storage system.

Pomegranatearils(100%usableform)wereextractedfromthesanitizedfruits and treatedwithfourdifferent solutions *viz*., 0.5% ascorbic acid,0.5%citricacid,1%calciumchlorideand1%calciumascorbatefor4minutes, air-driedand werekeptinarecasheathbowlswrapped withclingfilmalongwithuntreatedarils(control),underrefrigeration(5±2^{o}C) till the end of shelf life soastoform 5treatmentswith4replicationsinCompletelyRandomisedDesign.Thebestpre-treatmentsolutionwasselectedbasedon superior physiological (PLW, percent leakage), chemical (vitamin C, phenol) and sensory parameters of arils.

Inthesecondpart,fresh-cut pomegranate arils pre-treated withthe best solution were subjected to five differentpackaging systems *viz*., shrink wrappingin15µpolyolefinfilm,vacuumpackaging in laminated pouches, Modified Atmospheric Packaging (MAP)with N_2flushing in laminated pouches, aluminium tray wrapped with cling film andopen storage in paper plate (control) andstored under two different conditions *viz*., low temperature storage (10±5°C) andrefrigerated(5±2°C)storagetoform10treatmentswith2replicationsinaCompletelyRandomised Design.

Physiological, chemicaland sensory parameters of arils wererecordedatthetimeofstoragetilltheendofshelf-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. Sensoryparameterslikecolor,taste,appearance,flavourandtextureofpomegranatearilswereevaluated initially, one and two days afterstoragebyconductingorganolepticevaluation 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-cutpomegranatearilswas selected.

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 comapared 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.Pomegranate arils treated with 1%calciumascorbatehadminimum PLW (1.7%) andpercentleakage(51.68%) on 5.00 days after storage. Leastpercentleakageofpomegranatearilswasduetohighmembraneintegrity[7].

Table1.Effectofpre-treatmentsonphysiologicallossinweight(PLW)offresh- cutpomegranatearils

Treatments	PLW(%)

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	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	

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Table2.Effectofpre-treatmentsonpercent leakage offresh-cutpomegranatearils

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	

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ThevitaminCcontentofpre-treatedfresh-cutpomegranatearilsdecreasedduringstorageperiod.Similarresultwasobservedby[8].The decrease in vitamin C content of fresh-cutproduce during storage might be due to theoxidationofascorbicacidtodehydroascorbicacid,followedbyhydrolysis of the latter to 2,3-diketogulonicacid [9]. 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 [10]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 [11] 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[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.

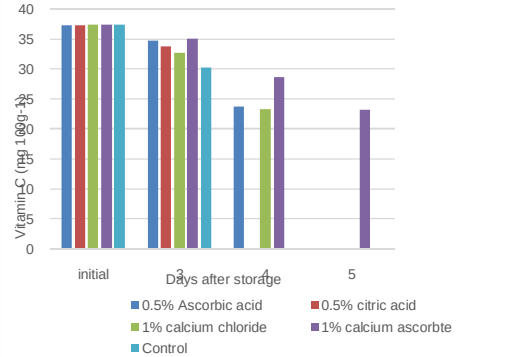

Fig 1. Effect of pre-treatments on vitamin C of fresh-cut pomegranatearils

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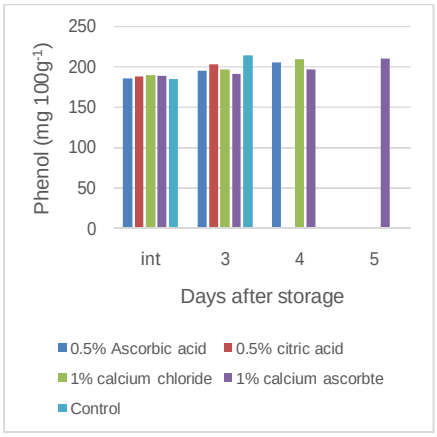

Fig 2. Effect of pre-treatments on phenol of fresh-cut pomegranatearils

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 ~~(P_1)~~ under low temperature storage ~~(S_1)~~ and the highest loss in weight (2.70%) was observed for arils without any package under refrigerated storage ~~(S_2).~~ After 2nd day of storage,arils in MAP with N_2 flushing in laminated pouches ~~(P_3)~~ 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% (Fig. 3).This result is in conformity with the findings of [13] 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).

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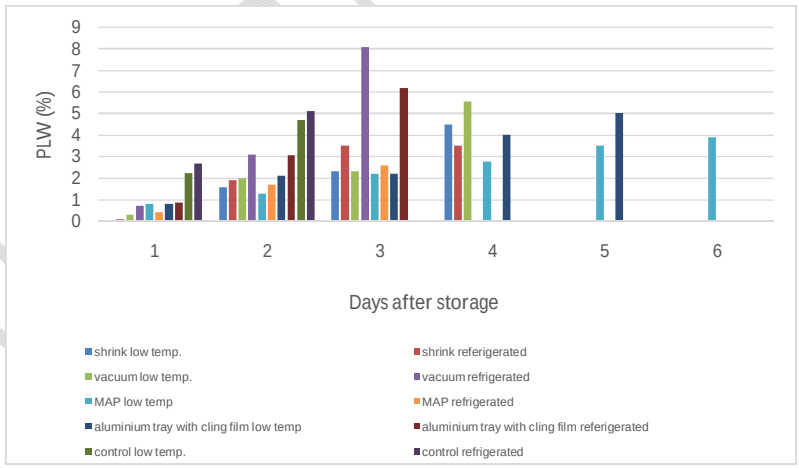

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Fig. 3. Effect of packaging and storage on PLW of fresh-cut pomegranate arils

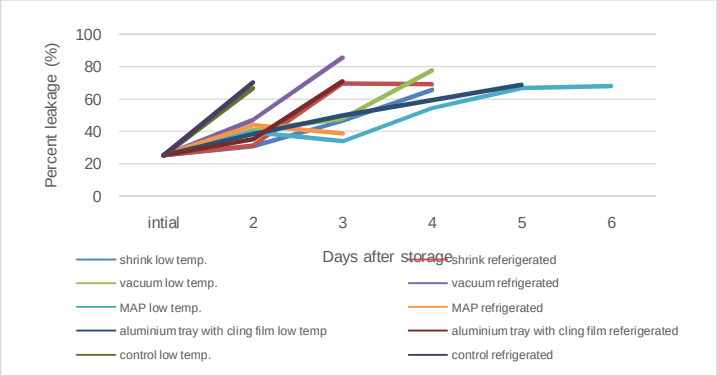

Fig. 4. Effect of packaging and storageon percent leakage of fresh-cut pomegranate arils

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 arilshad a vitamin C content of 30.00 mg100 g^{-1} and it reduced to 23.02 mg100 g^{-1} at the end of shelf life. The rate of degradation was low for arils in MAPwithN2flushinginlaminated pouches under low temperaturestorage 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]. Arils in MAP withN_2flushing inlaminatedpouchesstoredunderlowtemperatureconditionwereretained upto 6th day after storage with avitaminC of 23.02mg100g^{-1}.

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 phenol 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 [14],dippingoffresh-cutproduceincalcium ascorbate solutions had a positiveeffect on quality retention.

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[15]inpomegranatearils. MAPcouldresultinmaintainingabetterstructure, lower tissue damage and improvedqualitiesofarils duringstorage. [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 packagingmaterialsandstorageconditionsinmaintainingsuperiorphysiological, chemical and sensory parameters and shelf-life of fresh-cut pomegranate arils, 1% calcium ascorbatetreated arils kept in MAP with N_2flushing inlaminatedpouchesunderlowtemperaturestoragewasfoundtobethebesttreatment.

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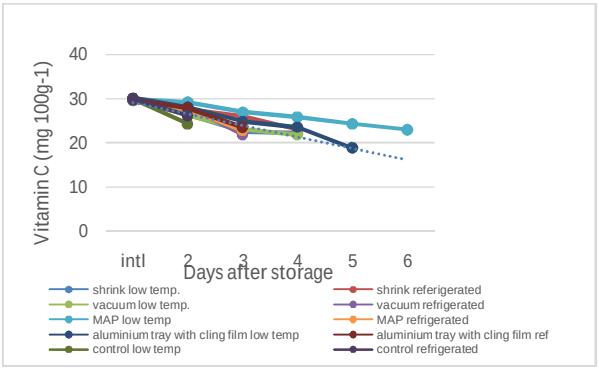

Fig. 5. Effect of packaging and storageon vitamin C of fresh-cut pomegranatearils

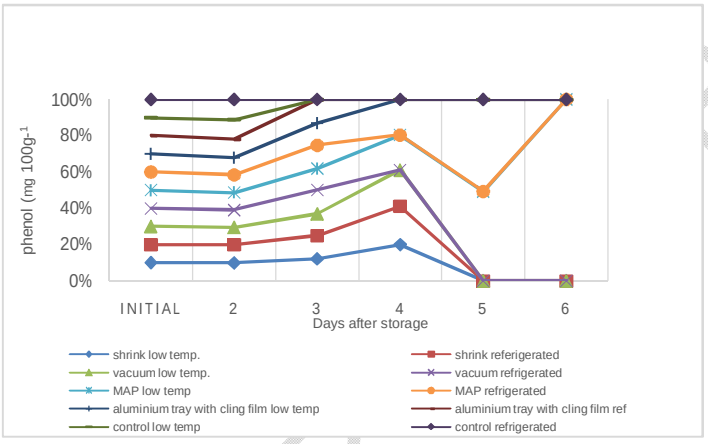

Fig. 6. Effect of packaging and storage on phenol of fresh-cutpomegranate arils

4. CONCLUSION

1% calcium ascorbatewasselectedasthebestpre-treatmentsolution for fresh-cut pomegranate arils withsuperiorphysiological, chemicaland sensory parameters. The physiological lossinweight,percentleakage,ascorbicacid andphenolcontentoffresh-cutpomegranate arils were influenced bypackaging materials, storage conditions and their interaction. Arils pre-treated with1%calciumascorbateandkept in MAPwith N_2 flushinginlaminated pouches under lowtemperature(10±5°C)storageprovedtobethebestpackagingand storage systems with a shelf-lifeof6daysascomparedto2daysfor unpackagedarilsbyretainingfreshlikecharacterswithminimumlossinweight,percentleakage,phenolandmaximumvitamin C content. As they alter the surroundingatmosphere 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.

REFERENCES

1.IFPA,TheInternationalFreshcutProduceAssociation. IFPAhomepage (online). Fresh cut facts. 2004. http://www. Freshcuts.org.
2. RangannaS.Handbook of analysisand quality control for fruit and vegetable products. Tata McGraw-Hill Education; 1986.

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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(*Artocarpusheterophyllus*L.)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, CaputaG.Effects of calcium citrate andascorbateasinhibitorsofbrowningandsofteninginminimallyprocessed „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 (*Agaricusbisporus*) 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, Ansarifar E, MohammadianMoghaddam 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.

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