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Influence of packaging material on quality characteristics of minimally processed Mridula pomegranate (*Punica granatum*) arils during cold storage

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ABSTRACT

An experiment was conducted during 2011-2012 to observe the effect of packaging materials (Polypropylene, low density polyethylene and cryovac KPA bags) with different water and gas transmission rate on minimally processed Mridula pomegranate (*Punica granatum*) arils stored at 5 ± 2 ºC and 85 ± 5 % RH for 15 days. The quality of minimally processed arils was determined by measuring colour attributes (a* and b* value), physiological loss of weight (PLW), total soluble solids (TSS), aril firmness, respiration rate and total sugars at 3 day interval. The results indicated that packaging material influenced PLW, TSS, aril firmness, respiration rate and total sugars. Overall, arils packed in PP bags maintained better colour (a* and b* value) and aril firmness as compared to LDPE and KPA packed arils. Arils packed in PP showed a lower PLW, TSS and total sugars than samples packed in LDPE and KPA. Arils packed in PP bags also showed lowest mean respiration rate (44.73 ml CO_2/kg/h) followed by arils packed in LDPE (50.19 ml CO_2/kg/h),) and KPA (52.80 ml CO_2/kg/h) at the end of storage. Among tested packaging materials, PP bags maintained better quality characteristics of minimally processed arils up to 15 days storage period.

Key words: Aril firmness, Minimal processing, Packaging, Pomegranate, Quality

Due to ever increasing life style and degenerative diseases, consumer's inclination towards fruit and vegetable based health promoting foods is growing fast. In addition to their nutritional composition and sensory attributes, foods are currently recognized as active and protective agents. Among all foods, fresh-cut or minimally processed horticultural produce are recognized as novel foods with innovative concept that fullfill the demand of modern lifestyle as they provide convenience, fresh, safe, nutritious and healthy products (Olivas and Barbosa-Canovas 2005).

Pomegranate (*Punica granatum* L.) is a choicest fruit mainly due to its exceptional and unique sensory and nutritional properties. Pomegranate fruits are highly nutritious and contain considerable amount of proteins, carbohydrates, minerals, sugars and crude fibres (Mir *et al.* 2007 and Marathe *et al*. 2010). It is also rich in functional compounds such as vitamin C, phenols and anthocyanins which act as antioxidants and protects human body from oxidative stress (Zaouay *et al*. 2012).

With increasing demand for fresh and natural products without addition of harmful chemicals, packaging film seems to be an ideal tool for preservation of minimally processed fruits, being cheap and easy to apply. Selection of packaging material is very important as combination of horticultural produce and permeability of film results in the passive evolution of an appropriate atmosphere within sealed packages (Jacobsson *et al*. 2004). The modification of carbon dioxide and oxygen concentrations in the packages could help to maintain freshness and visual appearance of fresh-cut produce by reducing respiration and ethylene production, and/or physiological and pathological deterioration during storage (Rocha *et al*. 2003). Previous findings indicated that packaging material also influence the nutritional and sensory quality of minimally processed produce (Jacobsson *et al*. 2004 and Shiri *et al.* 2011).As evident from earlier findings that the response of the individual packaging film in relation to shelf-life and quality greatly varied with crop and even within the crop varieties. Looking into these gaps, the present study was undertaken to determine the effect of packaging materials (PP, LDPE and KPA) with different water and gas transmission rate on quality of minimally processed Mridula pomegranate arils during cold storage.

MATERIAL AND METHODS

Pomegranate fruits of Mridula cultivar harvested at

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Table 1 Thickness, water vapour transmission rate (WVTR) and oxygen transmission rate (OTR) of selected films used for packaging of minimally processed pomegranate arils

Packaging material	Thickness (µm)	WVTR (cm^3/m^2/24 hr)	OTR (cm^3/m^2/24 hr)
PP	40	1.4	2701.73
LDPE	50	5.6	6313.761
KPA	90	15	35

PP- Polypropylene; LDPE- Low density polyethylene; KPA- Cryovac based high barrier laminate pouches

physiological maturity (Total soluble solids ranging from 11 to 12 °Brix) from experimental orchard of Mahatma Phule Agricultural University, Rahuri during harvesting seasons of 2011, 2012 and immediately transported to the postharvest handling laboratory and kept at 5 ± 2 ºC and 85 ± 5 % RH (relative humidity) until the next day. Pomegranates with defects were discarded and healthy ones uniform in size and appearance were sanitized with 200 µL/L chlorine solution. Husks (peel) were cut at equatorial zone with sharpened knife and arils were manually separated. Separated arils were collected in a tray and gently mixed to assure uniformity. Thereafter, arils were dipped in a solution containing 100 µL/L chlorinated water for 5 min, followed by rinsing with potable tap water at 5 ºC (Gil *et al.* 1996 b) and washed arils were air dried to remove surface water. Dried arils with sample size of 100 g were packed in three different packaging films made up of polypropylene (PP), low density poly ethylene (LDPE) and KPA (Cryovac, India). The thickness, water vapour transmission rate (WVTR) and oxygen transmission rate (OTR) of three packaging material used in present study are listed in Table 1. Packaged samples were stored at 5 ± 2 ºC and 85 ± 5 % RH for 15 days and sampling was carried out on 0, 3, 6, 9, 12 and 15 days of storage. Three packs were analyzed for each packaging material and parameter on scheduled sampling days.

Colour attributes (a* and b*) were measured using colour meter (colour tec PCM/PSM, USA), the instrument generates a set of Cartesian coordinate which pin point the measured colour in a three dimensional colour space. In the CIE (L*, a*, b*) colour space abbreviated CIELAB positive a* indicate a hue of red purple, negative a* indicates bluish green, positive b* and negative b* indicates yellow and blue respectively.

Arils were weighted during storage at regular intervals with the help of an electronic balance. Physiological loss in weight (PLW) was measured by subtracting the initial weight from final weight and expressed as per cent.

The total soluble solids of samples were estimated using Fisher Scientific hand refractometer. The results were expressed as ºBrix at 20 ºC.

Aril firmness was determined using a texture analyzer (model: TA+Di, Stable Microsystems, UK) using compression test. The sample was compressed using a cylindrical probe (75 mm diameter) by programmed settings as follows: Pre test speed 5 mm/sec, test speed 2 mm/sec, post test speed 10 mm/sec. First peak force (N) in the force deformation curve was taken as firmness of the sample.

Post-storage respiration rate was measured by placing arils in 150 ml capacity container hermetically sealed with a silicone rubber septum for 1 hr. After specified time, the head-space gas was sucked through a hypodermic hollow needle and the respiration rate was quantified by using auto gas analyzer (model: Checkmate 9900 O_2/CO_2, PBI Dansensor, Denmark). The rate of respiration was expressed as ml CO_2/kg/hr.

Total sugar**s** were determined by the method described by AOAC (1980) and results were expressed in percentage (%).

Data for the analytical determination were pooled and subjected to two-way analysis of variance (ANOVA) by taking packing material and storage days as the two sources of variations and the significant effects were noted. Further, it was subjected to multiple range comparison procedure to identify the pair-wise significant difference between the

Table 2 Effect of packaging material and storage period on colour attributes (a* and b*) of minimally processed pomegranate arils stored at 5 ± 2 °C and 85 ± 5% RH

	Packaging material (PM)	Storage period (days)						
		0	3	6	9	12	15	Mean (PM)
a*	PP	24.53±0.51 ^{a}	25.31±0.33 ^{ab}	25.98±0.51 ^{bc}	26.07±0.57 ^{bcd}	27.31±0.39 ^{defg}	27.92±0.97 ^{efgh}	26.19 ^{a}
	LDPE	24.53±0.51 ^{a}	25.93±0.51 ^{bc}	26.06±0.58 ^{bcd}	27.02±0.55 ^{cde}	28.38±0.64 ^{fgh}	28.92±0.98 ^{h}	26.81 ^{b}
	KPA	24.53±0.51 ^{a}	25.88±0.44 ^{bc}	27.12±0.55 ^{cdef}	28.04±0.49 ^{efgh}	28.52±0.24 ^{gh}	29.07±0.69 ^{h}	27.19 ^{b}
	Mean (Storage)	24.53 ^{a}	25.70 ^{b}	26.38 ^{bc}	27.04 ^{c}	28.07 ^{d}	28.65^{d}	
b*	PP	16.07±0.72 ^{a}	16.33±0.46 ^{a}	16.89±0.22 ^{bc}	17.86±0.95 ^{bcd}	18.39±0.24 ^{cde}	18.92±0.61 ^{de}	17.41 ^{a}
	LDPE	16.07±0.72 ^{a}	17.21±0.58 ^{abc}	17.71±0.55 ^{bcd}	18.52±0.44 ^{de}	18.83±0.13 ^{de}	19.01±0.66 ^{de}	17.89 ^{a}
	KPA	16.07±0.72 ^{a}	17.84±0.05 ^{bcd}	18.66±0.84 ^{de}	19.33±0.84 ^{ef}	19.62±0.56 ^{ef}	20.51±0.06 ^{f}	18.67 ^{b}
	Mean (Storage)	16.07 ^{a}	17.12 ^{b}	17.76 ^{b}	18.52 ^{c}	18.55 ^{cd}	19.48 ^{d}	

PP, Polypropylene; LDPE, low density polyethylene; KPA; a*, redness; b*, yellowness; Values are expressed as mean ± standard deviation; Means with same superscript are homogeneous effects. Results were given as mean ± standard deviation of three independent determinations. Differences were considered to be significant at P=0.05 (95% confidence level). All analyses were performed with SAS software package, version 9.3.

RESULTS AND DISCUSSION

Colour

Red colour of pomegranate arils is due to anthocyanin pigment and is a very important attribute of quality. Colour attributes (a* and b*) of minimally processed Mridula pomegranate arils packed in three packaging material (PP, LDPE and KPA) were studied during the storage period of 15 days (Table 2). The Packaging materials and storage days exhibited significant ($P \leq 0.05$) effect, whereas their interaction showed insignificant ($P>0.05$) effect on a* and b* value of pomegranate arils. Ayhan and Esturk (2009) reported insignificant effect of MAP and storage time on a* and b* value of minimally processed arils during cold storage. Increase in a* and b* value of arils packed in three different packaging material indicates progression of aril browning during entire storage period. Similar trend in colour attributes (a* and b*) were also observed in fresh cut produce during storage (Rocha *et al.* 2003 and Xing *et al.* 2010). Minimally processed Mridula arils packed in PP bags showed least changes in colour attributes (a* and b*) indicating least browning compared to LDPE and KPA packed arils. Colour retention is related to prevention of moisture loss and/or anthocyanin degradation due to oxidative or enzymatic browning (Kim *et al.* 1993). Better colour retention in PP packed arils might be attributed to both the minimum WVTR and OTR compared to LDPE, although the factual OTR of KPA is far lower than PP and LDPE but it could not be able to exert better results due to poor water barrier properties.

Physiological loss in weight

Table 3 depicts the effect of packaging material and storage on PLW of minimally processed pomegranate arils during cold storage (5 ± 2 °C and 85 ± 5% RH). There was significant effect of packaging material, storage days and their interaction on PLW of pomegranate arils ($P \leq 0.05$). As a general trend PLW of pomegranate arils packed in three different packaging materials (PP, LDPE and KPA) increased during storage. Samples packed in PP showed a lower PLW over LDPE and KPA packed samples. The weight loss is a natural consequence of the catabolic process of harvested horticultural produce which is further accelerated by minimal processing operations. The PLW of produce is related to WVTR of packaging material (Conte *et al.* 2009 and Lucera *et al.* 2010), respiration rate (Valero *et al.* 1998) and other senescence-related metabolic processes during storage (Watada and Qi 1999). These results are in agreement with the lower WVTR of PP over LDPE and KPA bags (Table 1). The findings are further ascertained that arils packed in PP also exhibited lower respiration rate followed by LDPE and KPA (Table 3).

Total soluble solids

TSS of arils was significantly affected by packaging materials, storage days and their interaction (P = 0.05) (Table

Table 3 Effect of packaging material and storage period on PLW (per cent), TSS (ºBrix) and aril firmness (N) of minimally processed pomegranate arils stored at 5 ± 2 °C and 85 ± 5% RH

	Packaging material (PM)	Storage period (days)						
		0	3	6	9	12	15	Mean (PM)
PLW	PP		0.007±0.002 a	0.035±0.001 d	0.065±0.003 f	0.127±0.001 i	0.162±0.002 l	0.079 a
	LDPE		0.012±0.001 b	0.052±0.001 e	0.073±0.001 g	0.146±0.002 k	0.176±0.002 n	0.091 b
	KPA		0.026±0.002 c	0.096±0.001 h	0.134±0.001 j	0.172±0.002 m	0.195±0.002 n	0.124 c
	Mean (Storage)		0.015 a	0.061 b	0.090 c	0.148 d	0.177 e	
TSS	PP	16.1±0.45 ef	16.20±0.20 ef	16.40±0.10 e	16.66±0.05 cde	16.16±0.15 ef	15.70±0.10 f	16.20 c
	LDPE	16.1±0.45 ef	17.50±0.13 b	17.23±0.15 bc	17.10±0.10 bcd	16.63±0.15 de	16.20±0.20 ef	16.79 b
	KPA	16.1±0.45 ef	17.63±0.15 b	18.40±0.60 a	18.83±0.05 a	17.43±0.15 b	17.10±0.10 bcd	17.58 a
	Mean (Storage)	16.1±0.45 d	17.11 b	17.34 ab	17.53 a	16.74 c	16.33 d	
Aril firmness	PP	208.63±1.44 a	207.71±2.32 ab	196.48±0.60 c	186.92±1.17 d	177.25±2.87 e	166.36±2.06 f	189.72 a
	LDPE	208.63±1.44 a	202.91±1.91 b	189.16±1.28 d	175.76±1.40 e	164.99±1.85 f	151.99±1.03 g	182.24 b
	KPA	208.63±1.44 a	196.84±1.23 c	176.69±1.52 e	166.53±1.57 f	155.67±3.60 g	133.02±1.73 h	172.89 c
	Mean (Storage)	208.63 a	202.48 b	187.44 c	176.40 d	164.30 e	150.46 f	

PP, Polypropylene; LDPE, low density polyethylene, KPA; Values are expressed as mean ± standard deviation; Means with same superscript are homogeneous

3). Irrespective of packaging material, TSS of pomegranate arils increased till 9th day of storage and thereafter declining trend was observed. Minimally processed pomegranate arils packed in KPA showed highest retention of TSS followed by LDPE and PP. TSS may be attributed to loss of water (Tanada-Palmu and Grosso 2005) and changes in metabolic activities of pomegranate arils during storage. As we found in our study too, that arils packed in PP, LDPE and KPA bags showed variation in PLW and being the maximum with KPA. Ayhan and Esturk (2009) also observed that TSS of modified atmosphere packaged ready to eat pomegranate arils started to decline after 9th day of storage period. Sepulveda *et al.* (2000) also found that water loss of arils packed in perforated packages led to increase in soluble solid content. Artes *et al*. 2000 also reported slight changes in TSS of pomegranate during cold storage. Decline in TSS during later phase of storage might be due to conversion of sugars into other organic acids such as citric, malic, oxalic and succininc.

Aril firmness

Aril firmness was found to be significantly affected by packaging material, storage days and their interaction ($P \leq 0.05$). In present study, progressive reduction of aril firmness was observed during entire storage period (Table 3). Mean average value of aril firmness packed in PP, LDPE and KPA was found to be 189.72 N, 182.24 N and 172.89 N respectively. Arils packed in KPA bags showed highest loss of firmness, whereas arils packed in PP bags exhibited least changes in firmness. Djioua *et al*. (2009) also reported loss of firmness in fresh cut mango during storage period. Loss of firmness during storage and distribution is a fundamental problem in shelf life extension of fresh cut produce and it generally changes over time as a result of tissue stresses during processing, action of endogenous enzymes related to cell wall degradation and microorganisms (Soliva-Fortuny *et al*. 2002). The variation in aril firmness has been found to be linked with water loss (Ayhan and Esturk 2009) and CO_2 concentration inside the packaging bags (Jacobsson *et al.* 2004). Maximum water loss in KPA packed arils due to high WVTR as compared to PP and LDPE may have contributed to loss of aril firmness. Further, high gas barrier property of KPA bags may have led to accumulation of CO_2 inside the package during storage contributing to loss of firmness.

Respiration rate

Respiration rate of arils was found to be significantly affected by packaging materials, storage days and their interaction (Table 4). Among the packaging materials, arils packed in PP bags showed lowest mean respiration rate (44.73 ml CO_2/kg/h) followed by arils packed in LDPE (50.19 ml CO_2 kg/h),) and KPA (52.80 ml CO_2/kg/h). Irrespective of packaging films, respiration rate of arils showed progressive increase during the entire storage period. Lucera *et al.* (2010) also reported similar trend in minimally processed fresh-cut Zucchini. Increase in respiration rate (RR) of fresh-cut produce attributed to increase in metabolic activity due to minimal processing operations (Rivera-Lopez *et al*. 2005). Lower respiration in PP packed arils might be due to better control of in-package atmospheric conditions (Lewicki *et al*. 2001 and Conte *et al.* 2009).

Total sugars

There was significant effect of packaging material, storage days and their interaction on total sugars in pomegranate arils ($P=0.05$). Minimally processed pomegranate arils packed in KPA showed highest total sugars followed by arils packed in LDPE and PP (Table 4). Overall increase in total sugars content was observed till 9th day followed by declining trend during rest of storage period. Rocha *et al.* (2003) also reported decrease in total sugars

Table 4 Effect of packaging material and storage period on respiration rate (ml CO_2/kg/h), titratable acidity (per cent) and total sugars (per cent) of minimally processed pomegranate arils stored ad 5 ± 2 °C and 85 ± 5% RH

	Packagin material (PM)	Storage period (days) 0	3	6	9	12	15	Mean (PM)
Respira-tion rate	PP	25.56±0.87 ^{a}	31.72±0.58 ^{b}	36.70±0.89 ^{d}	46.41±0.49 ^{g}	55.28±0.77 ^{i}	72.71±0.16 ^{m}	44.73 ^{a}
	LDPE	25.56±0.87 ^{a}	34.46± 0.50 ^{c}	41.23±0.77 ^{e}	51.84±0.82 ^{h}	64.57±0.69 ^{k}	83.50±0.88 ^{n}	50.19 ^{b}
	KPA	25.56±0.87 ^{a}	36.26±0.32 ^{d}	44.26±0.63 ^{f}	57.14±0.81 ^{j}	68.23±0.50 ^{l}	85.34±0.58 ^{o}	52.80 ^{c}
	Mean (Storage)	25.56 ^{a}	34.14 ^{b}	40.73 ^{c}	51.79 ^{d}	62.69 ^{e}	80.52 ^{f}	
Total sugars	PP	7.72±0.05 ^{g}	8.15±0.005 ^{e}	8.27±0.05 ^{cd}	8.34±0.03 ^{c}	7.95±0.03 ^{f}	7.71±0.04 ^{g}	8.02 ^{c}
	LDPE	7.72±0.05 ^{g}	8.16± 0.01 ^{e}	8.53±0.03 ^{b}	8.66±0.01 ^{a}	8.20±0.04 ^{de}	7.88±0.02 ^{f}	8.19 ^{b}
	KPA	7.72±0.05 ^{g}	8.25±0.01 ^{d}	8.69±0.02 ^{a}	8.74±0.01 ^{a}	8.26±0.02 ^{cd}	7.95±0.03 ^{f}	8.27 ^{a}
	Mean (Storage)	7.22 ^{f}	8.19 ^{c}	8.50 ^{b}	8.58 ^{a}	8.14 ^{d}	7.8 ^{e}	

[1]PP, Polypropylene; LDPE, low density polyethylene, KPA; Values are expressed as mean ± standard deviation; Means with same superscript are homogeneous

content of fresh cut apples between 7th and 10th day of storage. Highest total sugars content in KPA packed arils attributed to highest water loss during entire storage period as compared to PP and LDPE bags. In present study, results of total sugars are in agreement with TSS content and recorded PLW trend. Increase in sugars content may be due to the breakdown of polysaccharides such as starch and hemicellulose into low molecular weight compounds such as simple sugars (Coseteng and Lee 1987). The declining trend at later phase is possibly attributed to utilization of sugars as a substrate in metabolic processes (Rocha *et al.*2003).

In the present study the effects of different packaging material (PP, LDPE and KPA) on the quality of minimally processed pomegranate Mridula arils were investigated. PP bags showed the potential to maintain the quality of minimally processed arils for 15 days stored at 5 ± 2 °C and 85 ± 5% RH. Arils packed in PP maintained better colour and firmness compared to LDPE and KPA packed arils. PP packed arils also showed low PLW, respiration rate, TSS and total sugars during entire storage period. These results suggest that PP packaging can be an effective alternative to maintain quality of minimally processed pomegranate arils. Due to increasing environment concern, there is needed to replace petrochemical based packaging material with biodegradable films. Therefore, further investigations are required to find out the commodity specific suitable biodegradable packaging materials.

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