



Pre-harvest bagging influences sunburn, cracking and quality of pomegranate fruits

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ABSTRACT

Purpose: Quality loss is high in pomegranate due to physiological disorders occurred during growth and developmental stages of fruit in main production areas in Iran. **Research method:** we evaluated the effects of preharvest fruit bagging time (July and August), and bag color (white and brown) on sunburn, cracking, anthocyanin content, and quality of pomegranate fruit. This experiment was carried out on eight-year-old pomegranate trees cv. Shishe-Kab in an orchard located in Ferdows, South Khorasan province, Iran. **Main findings:** The results showed that the maximum (90%) and minimum (25%) sunburn percentage was observed in control (non-bagged fruits) and white-bagged fruits at August (WBA), respectively. Similarly, the highest percentage of cracking (65%) and the lowest (5%) was obtained in control and WBA, respectively. Non-bagged fruits showed the highest (23.61 mg⁻¹) anthocyanin, and the lowest rate (13.55 mg⁻¹) observed in brown-bagged fruit in July (BBJ). The brightness (L) of the peel color of brown-bagged fruit in August (BBA) was the highest while the lowest L value obtained in control and white-bagged fruits in July (WBJ). Bagging did not change the weight, volume, and pH of pomegranate juice. Interestingly, bagging in both white and brown bag effectively reduced fruit sunburn and cracking and decreased the total damaged fruits, particularly when fruits were bagged in August, as compared with non-bagged control. **Research limitations:** No limitations were founded. **Originality/Value:** The results suggest that proper pre-harvest bagging to improve the quality and reduce losses of pomegranate fruit cv. Shishe-Kab.

INTRODUCTION

Pomegranate is one of the most Iranian popular fruits that being widely consumed fresh (arils) and in processed forms such as juice, jelly, paste, and vinegar (Ben-Arie et al., 1984). Pomegranates are picked late in summer to early in autumn, therefore exposing the fruits to high temperatures and extreme light throughout the summer. As a result, the incidence of sunburn damage can be high causing grower losses that may exceed 30% of the harvested fruit (Melgarejo & Martinez, 1992). Sunburn damage of pomegranate called blacking occurred on the sun-exposed side of the fruit when the surface temperature reached up to 45-50°C (Yazici & Kaynak, 2006). Sunburn is a physiological disorder resulting from the combined action of high solar radiations, high temperatures and low humidity, which leads to losses in yield and quality and burns fruit surface and changes its peel colour in the form of large black spots on the fruit skin (Pareek et al., 2015). In this case, the appearance quality of fruits decreases results in major economic losses (Finkel & Holbrook, 2000). Pomegranate fruits are sensitive to sunlight because they are terminal-bearing plants, with thin branches that bend with the increase in fruit size and weight as the season progresses (Pareek et al., 2015). Thus, this exposes fruit parts to more direct sunlight during summer and increase sensitivity to sunburn.

Pre-harvest fruit bagging has emerged as a novel technology in practice, which is simple, grower friendly and safe method (Sharma et al., 2014b; Haldankar et al., 2015). Preharvest bagging of fruit is commonly practiced in Japan, Australia, and China for peach, apple, pear, grape, and loquat fruits in order to get quality fruits and consequently better prices in the market (Sharma et al., 2014a). It is a physical protection method that can improve the appearance quality of fruits, protect fruits from pests and eliminates the use of pesticides, reduce the mechanical and bird damage (Abbasi et al., 2014; Chen et al., 2012; Lima et al., 2013; Sharma & Sanikommu, 2018). Bagging also improved fruit quality and promotes coloration in peaches (Jia et al., 2005), reduced incidences of fruit cracking in grape (Son and Lee, 2008), reduced sunburn and increase finger length and the bunch of banana fruit (Amarante et al., 2002). However, there have been inconsistency reports on the effects of preharvest fruit bagging on size, maturity, peel colour and fruit quality as reviewed by Sharma et al. (2014a), which may reflect differences in the type of bag used, fruit age at bagging, date of bagging and duration of exposure to light following bag removal, cultivar, climatic conditions and conditions of maintaining fruit after harvest. The type of bag used influences the physiological response of fruit to bagging. For example, in 'Keitt' mango, white paper bagging increased the percentage of yellow skin area compared to non-bagged fruit (Hofman et al., 1997). Recently, non-woven polypropylene bags have been replacing paper bags and improved fruit quality has been reported in several fruit crops including pear, grape, and peach (Huang et al., 2014).

Pomegranate cv. Shishe-Kab is one of the important commercial varieties grown in dry and warm areas of South Khorasan province, Iran (Moradinezhad et al., 2019). In recent years, mainly due to high temperatures and radiations, pomegranates are severely sunburnt and resulted in not only low-quality fruit appearance but also discolored arils in the sunburnt area. However, little information is available regarding the effect of fruit bagging on sunburn and quality of pomegranate fruit, particularly in Shishe-Kab cultivar. The aim of this study, therefore, was to investigate the effect of pre-harvest bagging date and bagging with different colours on sunburn and quality attributes of pomegranate fruit cv. Shishe-Kab.

MATERIALS AND METHODS

Plant material and experiment preparation

The experiment was conducted on an eight-year-old pomegranate cv. Shishe-Kab orchard located in Ferdows, South Khorasan province, Iran. A randomized complete block design with four replicates (five trees per plot) and five fruit per tree for each treatment was used. Fruits were selected randomly from different sides of the tree and then bagged for each treatment. Single-layer cloth bags (Tina Pack Co., Tehran) in two colours (white and light brown) were placed over fruits on 1st of July (when the fruit diameter was about 3 cm) and 30 days later on 1st of August 2015 until harvesting time. Bags had a thickness of 0.17 mm, size of 15 × 20 cm and were secured by stapling the bag tightly around the fruit peduncle. Instead of a complete cover, we used open bags at the bottom to provide better ventilation and light. However, bagged fruits completely were covered until harvest time because the fruit size was smaller than the bag used. Fruits in control trees were not bagged. Colour characteristics of used bags are shown in Table 1.

The air temperature was recorded using data logger (Extech Instruments, Model RHT20, Humidity and Temperature Datalogger, USA). Bag and fruit temperature were measured by a compact infra-red thermometer with laser pointer (Extech Instruments, Model 42500, Mini IR Thermometer, USA), so that to measure the surface temperature of the fruit, three fruits selected in each tree and the compact placed on fruit and to measure bag surface temperature, Laser of compact was flash from a distance of 30 cm from the bag. Air temperatures were recorded in the shade outside the bag. Bag surface temperature was measured as fruit temperature. Fruit temperatures were recorded on both sides of the fruit surface. Values represent the results for an average of two typical days in each month with a clear sky at 3:00 pm. The fruits were picked up at commercial maturity, early in November and immediately after harvest transferred to the laboratory for different assessments.

Sunburn, cracking and physicochemical assessments

The percentage of sunburnt fruit was measured based on the number of fruits sun scalded to the fruits of each treatment. For severity assessment of sunburn, fruit were classified into four groups based on their severity of sunburn: no sunburn damage = 0, sunburn including stains yellow mild =1, sunburns middle bronze and brown spots =2, sunburn large includes black spots=3 (Glenn et al., 2002). The percentage of cracked fruit was calculated based on the number of fruits cracked to the fruits of each treatment. Juice weight was determined by a precision digital balance with an accuracy of 0.01 g. Juice volume also was determined by a graduated cylinder. The pH of juice was also evaluated using a digital pH meter (Extech Co, USA).

Table 1. Colour parameters of light brown and white cloth bags used

Colour of bag	$L^*†$	a^*	b^*	C^*	h°
Light brown	57.03	15.15	16.3	22.6	46.61
White	98.87	2.41	4.62	5.21	297.5

† L^* : (0, dark; 100, white), a^* : (negative value, green; positive value, red), and b^* : (negative, blue; positive, yellow).

Colour attributes

For determination of fruit colour, the peel colour of 5 randomly-selected bagged or non-bagged fruits from each treatment was determined using of colormeter (TES-135A, Taiwan) and was expressed in L^* values (0, dark; 100, white), a^* values (negative value, green; positive value, red), and b^* values (negative, blue; positive, yellow). The colour degree (hue angle) was calculated from the following equation (1).

$$(1) h^\circ = \arctan \frac{b}{a}$$

The colour intensity (chroma) was calculated from the following equation (2).

$$(2) C = \sqrt{a^2 + b^2}$$

Anthocyanin content

Total anthocyanin content (TAC) was determined spectrophotometrically by the pH differential method (Giusti & Wrolstad, 2003). Absorbance was measured at 510 and 700 nm in buffers at pH 1.0 and 4.5 using a spectrophotometer and then calculated according to the following equation (3):

$$(3) A = [(A_{510} - A_{700})_{pH1.0} - (A_{510} - A_{700})_{pH4.5}].$$

Results were expressed as mg of cyanidin-3-glucoside per 100 mL of juice, using a molar absorptive coefficient (ϵ) of 26,900 and a molecular weight of 449.2, and then total anthocyanin content was calculated as follows (4):

$$(4) \text{Total anthocyanin (mg/l)} = \frac{A \times MW \times DF \times 1000}{\epsilon}$$

Where A=absorbance; MW= molecular weight of cyanidin-3-glucoside; DF=the degree of dilution; ϵ = molar absorptive coefficient.

Statistical Analysis

The experiments were conducted using a completely randomized block design. Data from the analytical determinations were subjected to analysis of variance (ANOVA). Mean comparisons were performed using the LSD test ($P < 0.05$). All analyses were performed with the SAS program (version 8, Institute Inc., Cary, USA). Mean comparisons of bag colour and bagging time were subjected to orthogonal functions. Also, the correlation was performed with SPSS (version 25) program.

RESULTS AND DISCUSSION

Bagging with brown colour increased fruit peel temperature within the bags, while white bags decreased compared to non-bagged (control) pomegranate during growth and development months (Table 2). In July the typical summer month with the air temperature at 36.8 °C, the maximum fruit temperature (40.8 °C) recorded in brown bags and the lowest (32 °C) with white bags (Table 2).

Sunburn percentage and severity

The results showed that bagging had a significant effect ($p \leq 0.05$) on the percentage and severity of fruit sunburn (Table 3). The highest percentage of sunburn (90%) was obtained in control (non-bagged fruit) and the lowest (25%) in bagged fruit with white bags in August (WBA). The highest (1.6) severity of sunburn was found in control and the lowest (0.42) in bagged fruit with brown bags in August (BBA). The results of bagging time showed that this factor had a significant effect on the percentage and severity of fruit sunburn as more sunburn observed in July (1.01) compare to August (0.43). This is in agreement with the results of Ehteshami et al. (2015) that reported bagging fruit of pomegranate cv. Robab-Neyriz with white and green bag reduce percentage and severity of sunburn. Regardless of the colour, bagging date was more effective in sunburn reduction as interestingly, delayed bagging in August had lower sunburn compared to July. However, there was no significant difference between white and brown bags in sunburn percentage. As shown in Table 5 the maximum fruit temperature in the white bag was lower than brown bag and control (non-bagged) fruit. Light radiation during the summer results in excessive light and heat load on leaves and fruit. Although the relative contribution of heat and light stresses to sunburn is not yet clearly established, sunburn is caused by the interaction of high temperature and light (Glenn et al., 2002). Han et al. (2002) noted that the temperature inside the bag was correlated with the physicochemical characteristics of the bag, i.e. light reflectance, absorbance and transmittance, and air permeability. Also, Amarante et al. (2002) reported that pre-harvest bagging of 'Doyenne du Comice' pear increased the percentage of fruit that was accepted for export primarily by reducing skin blemishes.

Our result regarding sunburn in pomegranate fruit supporting previous reports who noted that reducing the surface temperature of the fruit reduces sunburn in many fruits (Glenn et al., 2002). Observation showed that sunburn damage occurred on Hicaznar pomegranate cultivar when the air temperature was higher than 30 °C and solar radiation was higher than 610 W m^{-2} (Yazici & Kaynak, 2006). Our experiment had similar results as white-bagged fruits had a lower temperature than brown-bagged fruits and non-bagged fruit during summer. This is almost certain, due to more reflection of the sun in a white bag than brown bag. However, bagging fruits in August was more effective in sunburn reduction than July. This could be attributed to proper bagging date in regards to the growth and development stages of pomegranate fruit and other environmental factors such as solar radiation. Therefore, July, August and September were determined to be high risk months for sunburn damage. It has been reported that shading treatments were also effective against sunburn damage on pomegranate fruits (Yazici & Kaynak, 2006) and apples (Arndt, 1992) compared to the control.

Table 2. Maximum air temperature, bag surface temperature, and fruit surface temperature (°C) of bagged and non-bagged (control) pomegranate from July to November 2015

Month	Maximum air temperature (°C)	Bag temperature (°C)		Fruit temperature (°C)		
		White	Brown	Control	White bag	Brown Bag
July	36.8	34.2	46.8	35	32	40.8
August	34.7	32.8	44.5	34	30.6	38.5
September	31.4	29.4	41.3	30	27.4	35.3
October	28.2	26.2	38.2	27	24	32.2
November	19.1	17.2	30.1	18	16	24

Table 3. Effect of the colour of bag and bagging date on sunburn, cracking and some physicochemical properties of pomegranate fruit cv. Shishe-Kab

Treatments*	Sunburn severity	Sunburn (%)	Cracking (%)	Anthocyanin (mg/l)	pH	Juice weight (g)	Juice volume (ml)
Control	1.60a †	88.0a	65.0a	23.61a	4.93a	117.81a	112.69a
WBJ††	0.85bc	59.0b	21.0bc	20.35ab	4.85a	129.67a	123.56a
BBJ	1.17ab	65.0ab	33.0b	13.55c	4.95a	129.75a	121.71a
WBA	0.43c	26.0c	5.0c	16.00bc	4.93a	114.43a	109.00a
BBA	0.42c	30.0c	10.0c	11.46c	4.80a	115.19a	112.06a

† Columns with different letters indicate significant differences at $P \leq 0.05$ according to LSD test.

† † WBJ, (White bag early in July); BBJ, (Brown bag early in July); WBA, (White bag early in August); BBA, (Brown bag early in August).

Cracking percentage

Bagging reduced fruit cracking significantly compared to non-bagged fruit. The results showed that the highest percentage of cracking (65%) was found in control and the lowest (5%) in white-bagged fruits in August (WBA) (Table 3). In addition, the time of bagging significantly affected cracking as bagged fruit in August had a lower cracking percentage (7.72%) than July (38.63%) (Table 5). However, bag colour had no significant effect on fruit cracking.

Previous studies showed that the bagging reduced the incidence of cracking in litchi (Oosthuizen, 1989) and nectarine (Ding et al., 2004) fruit. Bagging with different materials showed differential effects on the incidence of fruit cracking (Yang et al. 2009). The temperature change in a day can be a major factor especially in fruit cracking (Mohseni, 2010). In a study on longan fruit, black adhesive-bonded fabric bag, and white adhesive-bonded fabric bag treatments significantly reduced fruit cracking in compared with the control (Yang et al. 2009). This is in agreement with our results as both of bag colour reduced fruit cracking.

Genetic differences in susceptibility to peel cracking, between cultivars of a species, have been correlated with fruit size, shape, cuticle, sugar level, growth and development (Emmons & Scott 1998). Cracking, not only affected by factors such as irregular irrigation, untimely rainfall, strong winds and hot, but also sunburn phenomenon (Ranjbar et al., 2004). Environmental conditions especially temperature and humidity (Peet, 1992) are effective in inducing fruit cracking. Bagging is capable of maintaining moisture around bagged fruit and avoids direct strong and hot winds to the skin of fruit and therefore can be effective in reducing this disorder as cracking in pomegranate resulted from the pressure of the quickly expanding arils on the stretched peel (Yilmaz & Özgüven, 2006).

Anthocyanin

The results of this study showed that bagging had a significant effect ($p \leq 0.05$) on anthocyanin content of pomegranate fruit (Table 3). Bagging decreased anthocyanin content significantly, compared to the control. However, white-bagged fruit in July (WBJ) showed no significant reduction in anthocyanin content. The non-bagged fruit (control) had the highest (23.61 mg^{-1}) anthocyanin value, while the lowest value (13.55 mg^{-1}) was in brown-bagged fruit in July (BBJ). The colour of the bags also showed a significant effect on anthocyanin content. Data indicated that brown-bagged fruits had lower anthocyanin compared with white-bagged and non-bagged fruit.

It has been stated that bagging increases light sensitivity of fruit and stimulates anthocyanin synthesis when fruits are re-exposed to light after bag removal (Kim et al., 2010). It is not only the time of bagging or the kind of bag which influences fruit size, colour, and the quality of fruit, but the date of bag removal also plays a critical role. It has been

previously found that bagging in apple has a strong inhibition of skin colour development, primarily because bagging intercepts light, which is required for anthocyanin synthesis (Saure, 1990). However, further studies revealed that the date of bag removal had a greater influence on colour development in apple (Ju et al., 1995). Anthocyanin accumulation in plants is sensitive to environmental conditions (Oren-Shamir, 2009). In general, if bags are removed from fruit on the date of harvest, it is likely that the fruit will display poor colour development; however, if the bags are removed a few days before harvest, the fruit are likely to develop a more attractive colour than non-bagged fruit (Ju et al., 1995). Similarly, in our study bags are removed on harvest time, thus the anthocyanin content of colour bags was lower than in non-bagged fruit. This is also in agreement with the results of Ehteshami et al. (2015) that reported bagging fruit of pomegranate cv. Robab-Neyriz with white and green paper bag reduce anthocyanin content. This could be attributed to the lower fruit temperature in white-bagged fruit compared with brown-bagged. As shown in Table 2, white-bagged fruit experienced lower temperatures than brown bags during the growing season, resulting in greater production and accumulation of anthocyanin. Low temperatures enhance anthocyanin accumulation (Oren-Shamir, 2009; Tarara et al., 2008) whereas at high temperatures the pigment concentration is reduced (Tarara et al., 2008; Mori et al., 2007).

Juice pH, weight, and volume

Bagging showed no significant effect ($p \leq 0.05$) on the pH of juice (Table 3). The highest pH (4.95) was in brown-bagged fruit in July (BBJ) and the lowest pH (4.80) was found in August (BBA). There was no significant difference between juice weight of control and bagged fruits (Table 3). The highest fruit weight (129.75 g) was obtained in BBJ and the lowest (114.43 g) in WBA. Bagging had no significant effect on juice volume (Table 3). The highest juice volume (123.56 ml) was in bagged fruit in WBJ and the lowest (109 ml) in bagged fruit in WBA.

Peel colour attributes

Fruit peel colour was affected by bagging, like lightness, yellowness (b^*) and hue angle changed significantly. The lightness of brown-bagged fruit in August (BBA) increased significantly compared to other treatments (Table 4). This means that brown-bagged fruit had brighter peel colour which caused lower appearance postharvest quality. Also, the highest b^* and hue angle observed in brown-bagged fruit in July (BBJ) and the lowest in white-bagged fruit in July (WBJ).

Fruit skin colour is the principal attraction for consumers. An attractive skin colour improves the physical appearance of the fruit, which raises the market price. Previous studies have reported that apple fruit bagging inhibited colour development; however, it has now been established that fruit bagging is an effective way to promote anthocyanin synthesis and thereby improve fruit skin colouration in apple (Ju et al., 1995). It is believed that pre-harvest fruit bagging increases the light sensitivity of fruit, which stimulates anthocyanin biosynthesis when the fruit are exposed to light after bag removal (Ju et al., 1995). In our study, we did not remove the bag until harvest because we wanted to investigate the effect of bagging on fruit until harvest time. Fruit bagging retarded the formation of russet and made the skin bright (Hudina et al., 2012). Sand pears (*Pyrus pyrifolia* Nakai) bagged until harvest looked yellowish and had a high lightness value and hue angle (Huang et al., 2009). Also, Huang et al. (2009) reported that the hue angle of control fruit of red Chineses and pears during fruit maturation period was much lower than bagged fruit. This is in agreement with our results on fruit bagging to some extent, as brown-bagged fruit in July (BBJ) had a significant reduction

in hue angle compared to control. The inconsistency results of bag colour on fruit skin colour may be due to differences in the light reflectance, absorbance, or transmission patterns of each bag in the visible, far-red, and/or infra-red regions of the spectrum (Sharma et al., 2014a). The effect of fruit bagging on colour development depends on the stage of fruit development at which it is bagged, the bagging date, the kind of bag used, the date of bag removal, and the climatic conditions of the area (Ju et al., 1995; Amarante et al., 2002). Ju et al. (1995) reported that bagging inhibited the accumulation of anthocyanins in the skin of ‘Delicious’ apple fruit. Kwan et al. (2000) also reported that bagging ‘Yuzu’ citrus (*Citrus Junos* L.) fruit before early-September with recycled Japanese phone-book paper (PBP) resulted in less colouration than in non-bagged fruit; whereas, bagging in September or later resulted in a similar colouration to non-bagged fruit. Hu et al. (2001) reported that bagging ‘Feizixiao’ litchi fruit should be done from 15 DAFB (days after full bloom) until harvest for better skin colouration. Data showed that bagging of pomegranate fruit had no significant effect on a^* (redness) and C^* (colour intensity) values (Table 4).

Correlations

There were significant and negative correlations between fruit anthocyanin content and peel colour characteristics, lightness ($r^2 = -0.72$), b^* ($r^2 = -0.60$) and hue ($r^2 = -0.58$). Also, sunburn and cracking in pomegranate fruit were correlated significantly ($r^2 = 0.71$).

Table 4. Effect of the colour of bag and bagging time on peel colour attributes of pomegranate fruit cv. Shishe-Kab

Treatments*	L^*	a^*	b^*	Chroma	Hue
Control	36.95c †	52.14a	12.08b	53.29a	13.72bc
WBJ ††	35.23c	53.47a	6.37c	54.02a	6.28c
BBJ	43.67ab	51.14a	19.77a	54.74a	20.67a
WBA	40.15bc	54.67a	13.36b	55.96a	13.23bc
BBA	45.64a	52.39a	18.22a	55.17a	19.18 ab

† Columns with different letters indicate significant differences at $P \leq 0.05$ according to LSD test.

††*WBJ, (White bag early in July); BBJ, (Brown bag early in July); WBA, (White bag early in August); BBA, (Brown bag early in August).

Table 5. Effects of bag colour and bagging time on sunburn, cracking and some physicochemical properties of pomegranate fruit cv. Shishe-Kab

Trials	Bag colour		Bagging time	
	WB†	BB	July	August
Sunsald severity	0.64a ††	0.81a	1.01a	0.43b
Sunsald (%)	42.50a	47.50a	62.50a	27.50b
Cracking (%)	12.40a	22.62a	38.63a	7.72b
Anthocyanin (mg/l)	18.17a	12.51b	16.96a	13.73a
Juice volume (ml)	122.78a	121.62a	130.71a	113.68b
Juice weight (g)	130.21a	130.43a	139.25a	121.4b
Juice pH	4.89a	4.87a	4.90a	4.86a
L^*	36.31b	44.65a	39.20a	41.77a
a^*	54.07a	51.64a	52.31a	53.41a
b^*	8.74b	18.79a	13.07a	14.46a
Hue	9.13b	20.50a	13.98a	15.20a
Chroma	54.99a	55.05a	54.42a	55.63a

†† Mean values in each row, for each treatment in the evaluated parameter, followed by the same letter are not significantly different by the LSD ($P \leq 0.05$).

†WB, white bag; BB, brown bag.

CONCLUSION

In conclusion, bagging date influences on fruit quality and sunburn. Fruit bagging in August was more effective than July in reducing sunburn and cracking. This is likely due to greater air temperature that increased bag and fruit temperatures in July than August. Although both bagging dates decreased sunburn percentage compared to non-bagged fruit, however, bag removal is necessary a few weeks before harvest date to promote a good amount of anthocyanin in fruits. The colour of the bag also protected fruits against physiological disorders and promoted better colouration. Bagged fruits in white bags had the least amount of sunburn with better skin colouration rather than brown bags. Product quality, market-friendly and affordable price will increase by reducing the percentage of sunburnt fruit. On the other hand, sunburnt and cracked fruits are not suitable for market, storage, and processing so that the bagging method can greatly reduce pomegranate postharvest losses. Further studies need to be done to evaluate the effects of bagging date and different bagging materials on controlling sunburn and cracking to improve the quality of pomegranate fruit.

CONFLICT OF INTEREST

The authors have no conflict of interest to report.

REFERENCES

- Abbasi, N. A., Chaudhary, M. A., Ali, M. I., Hussain, A., & Ali, I. (2014). On tree fruit bagging influences quality of guava harvested at different maturity stages during summer. *International Journal of Agriculture and Biology*, 16(3), 543-549.
- Amarante, C., Banks, N. H., & Max, S. (2002). Effect of preharvest bagging on fruit quality and postharvest physiology of pears (*Pyrus communis*). *New Zealand Journal of Crop and Horticultural Science*, 30(2), 99-107. <http://dx.doi.org/10.1080/01140671.2002.9514204>
- Arndt, H.P. (1992). Apple shading to reduce heat damage. *Tree Fruit Leader* 1(1).
- Ben-Arie, R., Segal, N., & Guelfat-Reich, S. (1984). The maturation and ripening of the 'Wonderful' pomegranate. *Journal of the American Society for Horticultural Science (USA)*, 109, 898-902.
- Chen, C. S., Zhang, D., Wang, Y. Q., Li, P. M., & Ma, F. W. (2012). Effects of fruit bagging on the contents of phenolic compounds in the peel and flesh of 'Golden Delicious', 'Red Delicious', and 'Royal Gala' apples. *Scientia Horticulturae*, 142, 68-73. <https://doi.org/10.1016/j.scienta.2012.05.001>
- Chen, D. C., Li, P., Ouyang, R., Gao, F. F., Wang, H. C., Dong, J., & Hu, G. B. (2000, June). Effects of bagging on fruit coloration and phenylalanine ammonia lyase and polyphenol oxidase in 'Feizixiao' litchi. In *I International Symposium on Litchi and Longan* 558 (pp. 273-278). [10.17660/ActaHortic.2001.558.43](https://doi.org/10.17660/ActaHortic.2001.558.43)
- Ding, Q., Han, M., & Tian, Y. (2004). Effect of bagging on nectarine fruit quality and fruit cracking. *Journal of Northwest Sci-Tech University of Agriculture and Forestry (Natural Science Edition)*, 32(9), 81-83.
- Ehteshami, S., Sari-Khani, H., Ershadi, A., & Amiri-Parian, J. (2015). Effect of bagging on some qualitative properties and reduce sunscald of pomegranate cv. Robab-neyriz. *Iranian Horticulture of Science*, 45(4), 353-360.

- Emmons, C. L. W., & Scott, J. W. (1998). Ultrastructural and anatomical factors associated with resistance to cuticle cracking in tomato (*Lycopersicon esculentum* Mill.). *International Journal of Plant Sciences*, 159(1), 14-22.
- Finkel, T., & Holbrook, N. J. (2000). Oxidants, oxidative stress and the biology of ageing. *Nature*, 408(6809), 239-247. <https://doi.org/10.1038/35041687>
- Giusti, M. M., & Wrolstad, R. E. (2003). Acylated anthocyanins from edible sources and their applications in food systems. *Biochemical Engineering Journal*, 14(3), 217-225. [https://doi.org/10.1016/s1369-703x\(02\)00221-8](https://doi.org/10.1016/s1369-703x(02)00221-8)
- Glenn, D. M., Prado, E., Erez, A., McFerson, J., & Puterka, G. J. (2002). A reflective, processed-kaolin particle film affects fruit temperature, radiation reflection, and solar injury in apple. *Journal of the American Society for Horticultural Science*, 127(2), 188-193. <http://dx.doi.org/10.5539/jps.v4n2p12>
- Haldankar, P. M., Parulekar, Y. R., Kireeti, A., Kad, M. S., Shinde, S. M., & Lawande, K. E. (2015). Studies on influence of bagging of fruits at marble stage on quality of mango cv. alphonso. *Journal of Plant Studies*, 4(2), 12. <https://doi.org/10.5539/jps.v4n2p12>
- Han, J. H., Hong, K. H., Jang, H. I., Jo, I. H., Choi, J. J., & Lee, H. J. (2002). Effect of characteristics of the bags and microclimate in the bags on russet of 'Whangkeumbae' pear fruit. *Korean Journal of Horticultural Science and Technology*, 20(1), 32-37.
- Hofman, P. J., Smith, L. G., Joyce, D. C., Johnson, G. I., & Meiburg, G. F. (1997). Bagging of mango (*Mangifera indica* cv. Keitt) fruit influences fruit quality and mineral composition. *Postharvest Biology and Technology*, 12(1), 83-91. [https://doi.org/10.1016/S0925-5214\(97\)00039-2](https://doi.org/10.1016/S0925-5214(97)00039-2)
- Huang, C., Yu, B., Teng, Y., Su, J., Shu, Q., Cheng, Z., & Zeng, L. (2009). Effects of fruit bagging on coloring and related physiology, and qualities of red Chinese sand pears during fruit maturation. *Scientia Horticulturae*, 121(2), 149-158. <https://doi.org/10.1016/j.scienta.2009.01.031>
- Huang, K.K., Chen, K.S., Zhang, S., Pei, J.B. & Xi, D.J. (2014). Effect of nonwoven PP fruit bag on fruit qualities of 'Yuguan' pear. *South China Fruits*, 43, 111–112 (in Chinese).
- Hudina, M., Stampar, F., Orazem, P., Petkovsek, M. M., & Veberic, R. (2012). Phenolic compounds profile, carbohydrates and external fruit quality of the 'Concorde' pear (*Pyrus communis* L.) after bagging. *Canadian Journal of Plant Science*, 92(1), 67-75. <https://doi.org/10.1139/CJPS2011-095>
- Jia, H. J., Araki, A., & Okamoto, G. (2005). Influence of fruit bagging on aroma volatiles and skin coloration of 'Hakuho' peach (*Prunus persica* Batsch). *Postharvest Biology and Technology*, 35(1), 61-68. <https://doi.org/10.1016/j.postharvbio.2004.06.004>
- Ju, Z. G., Yuan, Y. B., Liou, C. L., & Xin, S. H. (1995). Relationships among phenylalanine ammonia-lyase activity, simple phenol concentrations and anthocyanin accumulation in apple. *Scientia Horticulturae*, 61(3), 215-226. [https://doi.org/10.1016/0304-4238\(94\)00739-3](https://doi.org/10.1016/0304-4238(94)00739-3)
- Kwan, D. K., DuckSoo, C., EunSik, K., KilHyun, H., KyeongHo, L., KwangSik, K., & KeunCheol, L. (2000). Fruit quality of Yuzu (*Citrus junos* L.) as influenced by bagging time and materials of bagging treatment. *Journal of the Korean Society for Horticultural Science*, 41(2), 190-193.
- Kyeong, Y. K., SamSeok, K., KwangSik, C., & SangBouk, J. (2010). Effects of bagging with different pear paper bags on the color of fruit skin and qualities in 'Manpungbae'. *Korean Journal of Horticultural Science & Technology*, 28(1), 36-40.
- Melgarejo, P. & Martinez, R.Y. (1992). El Granado. Ed. Mundi-Prensa, Madrid, 163 pp.
- Mohseni, A. (2010). Pomegranate (production manual). Nashre-Akhar Publication. Tehran. 216 pp.
- Moradinezhad, F., Khayyat, M., Ranjbari, F., & Maraki, Z. (2019). Vacuum packaging optimises quality and reduces postharvest losses of pomegranate fruits. *Journal of Horticulture and Postharvest Research*, 2, 15-26. <http://doi.org/10.22077/jhpr.2018.1775.1030>
- Mori, K., Goto-Yamamoto, N., Kitayama, M., & Hashizume, K. (2007). Loss of anthocyanins in red-wine grape under high temperature. *Journal of Experimental Botany*, 58(8), 1935-1945. <https://doi.org/10.1093/jxb/erm055>
- Oosthuizen, J. H. (1989). Is covering of litchi clusters worthwhile. *Information Bulletin Citrus and Subtropical Fruit Research Institute*, 199, 10-12.

- Oren-Shamir, M. (2009). Does anthocyanin degradation play a significant role in determining pigment concentration in plants? *Plant Science*, 177(4), 310-316.
<https://doi.org/10.1016/j.plantsci.2009.06.015>
- Pareek, S., Valero, D., & Serrano, M. (2015). Postharvest biology and technology of pomegranate. *Journal of the Science of Food and Agriculture*, 95(12), 2360-2379.
<https://doi.org/10.1002/jsfa.7069>
- Peet, M.M. (1992). Fruit cracking in tomato. *HortTechnology*, 2(2), 216-223.
- Ranjbar, V., Y. Asadi, M. Hoseininia & Behzadi Shahre-Babak, H. (2004). Pomegranate Guide (plantation, cultivation and harvesting). *Nashre Amoozeshe Keshavarzi. Publication*. Karaj. 154 pp.
- Sarkhosh, A., Zamani, Z., Fatahi, R., & Ebadi, A. (2006). RAPD markers reveal polymorphism among some Iranian pomegranate (*Punica granatum* L.) genotypes. *Scientia Horticulturae*, 111(1), 24-29.
<https://doi.org/10.1016/j.scienta.2006.07.033>
- Saure, M. C. (1990). External control of anthocyanin formation in apple. *Scientia Horticulturae*, 42(3), 181-218. [https://doi.org/10.1016/0304-4238\(90\)90082-P](https://doi.org/10.1016/0304-4238(90)90082-P).
- Sharma, R. R., Pal, R. K., Sagar, V. R., Parmanick, K. K., Paul, V., Gupta, V. K., & Rana, M. R. (2014b). Impact of pre-harvest fruit-bagging with different coloured bags on peel colour and the incidence of insect pests, disease and storage disorders in 'Royal Delicious' apple. *The Journal of Horticultural Science and Biotechnology*, 89(6), 613-618.
<http://dx.doi.org/10.1080/14620316.2014.11513128>
- Sharma, R. R., Reddy, S. V. R., & Jhalegar, M. J. (2014a). Pre-harvest fruit bagging: a useful approach for plant protection and improved post-harvest fruit quality—a review. *The Journal of Horticultural Science and Biotechnology*, 89(2), 101-113.
<http://dx.doi.org/10.1080/14620316.2014.11513055>
- Sharma, R. R., & Sanikomm, V. R. (2018). Preharvest fruit bagging for better protection and postharvest quality of horticultural produce. In *Preharvest modulation of postharvest fruit and vegetable quality* (Siddiqui, M.W. ed.) (pp. 455-489). Academic Press.
- Son, I. C., & Lee, C. H. (2008). The effects of bags with different light transmittance on the berry cracking of grape 'Kyoho'. *Horticulture Environment and Biotechnology*, 49(2), 98-103.
- Tarara, J. M., Lee, J., Spayd, S. E., & Scagel, C. F. (2008). Berry temperature and solar radiation alter acylation, proportion, and concentration of anthocyanin in Merlot grapes. *American Journal of Enology and Viticulture*, 59(3), 235-247.
- Yang, W. H., Zhu, X. C., Bu, J. H., Hu, G. B., Wang, H. C., & Huang, X. M. (2009). Effects of bagging on fruit development and quality in cross-winter off-season longan. *Scientia Horticulturae*, 120(2), 194-200. <https://doi.org/10.1016/j.scienta.2008.10.009>
- Yazici, K. & Kaynak, L. (2006). Effects of kaolin and shading treatments on sunburn on fruit of hicaznar cultivar of pomegranate (*Punica granatum* cv. Hicaznar). *I International Symposium on Pomegranate and Minor Mediterranean Fruits*, 818, 167-174.
<https://doi.org/10.17660/actahortic.2009.818.24>
- Yilmaz, C., & Ozguven, A. I. (2005). Hormone physiology of preharvest fruit cracking in pomegranate (*Punica granatum* L.). In *X International Symposium on Plant Bioregulators in Fruit Production* 727 (pp. 545-550). <https://doi.org/10.17660/actahortic.2006.727.67>

