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Trends in Pomegranate Sector: Production, Postharvest Handling and Marketing

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Abstract

Pomegranate (*Punica granatum* L.) tree was one of the first cultivated crops in the world and is being produced in many regions of the earth for many years. However, its consumption was very low mainly due to the hassle of extracting the arils for eating. Studies after 21th century reported superior pharmacological and therapeutic properties for pomegranate. Results of these studies caused a considerable increase in the consumption and this caused an increase in demand which required increase in the production to meet the demand. The need for increasing the production has led new studies about the challenges affecting production, postharvest handling and marketing of pomegranate fruits. This review aimed to discuss recent studies and technologies about pomegranate production.

Key words: pest management, fruit cracking, physiological disorders**,** chilling injury, postharvest storage

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Introduction

Pomegranate (*Punica granatum* L.) was believed to be firstly planted around 4.000 BC while it was mentioned in ancient literature by Dioscorides and Hippocrates, and even in both Bible and Quran. Recent scientific studies revealed the health benefits of pomegranate fruits (Gil et al., 2000; Jurenka, 2008; Haidari et al., 2009; Okatan et al., 2015) and caused it to be titled as "super fruit". Then, the consumption and thus the production of this highly valuable crop started to increase all over the world. However, the production is still limited mainly due to the physiological disorders, pest and disease problems and postharvest problems. Langley (2000) reported that "pomegranate represents regeneration, life and marriage in the Greek mythology". It is also believed to be originated in Iran and spread to world from there (Levin, 1994; Kahramanoğlu and Usanmaz, 2016).

Pomegranate seeds is not producing true-to-type, and its propagation is mainly done by vegetative parts (Jalikop and Kumar, 1990). Today, more than 500 varieties of pomegranates are being grown throughout the world (Kahramanoğlu and Usanmaz, 2016). This review paper summarizes the recent studies and trends in pomegranate production, postharvest handling and marketing.

Trends in Production and Marketing

No reliable information is available about the total pomegranate production in the world. It was estimated to be around 3 million tons in 2014 and 3.8 million tons in 2017. Due to the rapid increase in the production, it is highly difficult to calculate the total production. The top countries for the production of pomegranate are believed to be: India, Iran, Turkey, China, United States of America, Israel, Egypt, Spain, Afghanistan, Tunisia, Azerbaijan, Morocco, Argentina, Brazil, Chile, Peru, South Africa, Australia and Italy (Table 1). Pomegranate trees are known to be very sensitive against climatic conditions, i.e. water scarcity, heavy rain, nail, salinity, heat and etc. Since 2010, the seasons are becoming difficult for pomegranate producing countries due to extreme weather conditions. For example, India had quality issues in 2017 due to rain, where Egypt had quality issues due to heat (sunburn). The pomegranate fruit, due to its characteristics, is very easy to substitute by other crops. Moreover, it is very important for countries to produce at least same amount of product to protect their share in the market.

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Table 1. Global availability of pomegranates

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
India												
Iran												
Turkey												
USA												
Spain												
Israel												
Argentina												
Peru												
S. Africa												
China												
Egypt												
Afghanistan												
Tunisia												
Azerbaijan												
Australia												
Italy												

In almost all of the above mentioned countries, the production area and the consumption is increasing; but the productivity (yield) is decreasing due to weather conditions and pests. Some of the countries also facing with quality issues.

India:
Pomegranate is one of the most popular horticultural crops in India and the production is growing about 20 to 25% every year. India is the only country where the pomegranate fruits are available year round due to climate. Most important varieties in India are Bhagwa and Arakta and the market of the Indian pomegranates is Europe (mainly Germany), Middle East and Asia. They mainly supply the products to the markets in December, January and March. Venkatesha and Yogish (2016) reported that even there is an increase in the area of production, the yield of the fruit-bearing trees showing a decline in the last years.

Iran:
Iran is among the most important producers in the world. They are mainly producing for local markets due to the problems in exporting. Malas Yazdi is the most important variety being produced in Iran.

Turkey:
Turkey is one of the most important growers and players in the European market. Turkish pomegranates (mainly Hicaznar) are well known in Eastern Europe, but many farmers in Turkey started to remove pomegranate plants due to high production costs and storage problems (not Hicaznar but some of other varieties). On the other hand, there are some growers who are starting new plantations (mainly with Wonderful), thus the total area is increasing.

United States of America:
In United States of America, California produces more than 90% the pomegranates. Total production in the USA was about 400 tons in 2017. California faced with a 5-years drought problem and this has impacted pomegranate production too. It was reported that some growers resorted to pulling out their pomegranate trees to use water for other crops, such as almonds and pistachios (The Packer, 2014). About 40% of the total production is known to be exported to countries around the Pacific (including Australia, Japan and Mexico) and to Europe via the Netherlands.

Spain:
Spain is among the most important producers in Europe. The most commonly grown variety is the Mollar de Elche (Mollar grown in Elche region). The other important varieties are Wonderful, Acco and Smith. Estimated local consumption is about 30%. Main exporting counties for Spain is in Europe, but since the competition is growing, Spanish exporters are searching new markets in Middle East and Asia.

Israel:
Israel is the other important player in the European market. Warm weather also affected the quality of Israeli pomegranates in last years (mainly Wonderful, Emek and Acco). European market has different preferences about origins and size. Mainly, the northern countries prefer smaller sizes, while German and Eastern Europe prefers larger sizes of pomegranate fruits.

Argentina:
Argentina has different harvest season than the countries located in northern hemisphere. This makes it important for European market. Wonderful, Acco, Emek, Shany and Camel are the important varieties. Harvest mainly starts in March and the products are being exported to different countries including Brazil, North America, Celtral Europe and Asian countries.

Peru:
Peru has an increasing production and export of pomegranates for many years. The main customers of Peruvian pomegranates are Europe, the UK, Canada and Asian countries. Peru has same season with other countries located in southern hemisphere and are competing for same markets, mainly in Europe.

South Africa:
Major varieties in South Africa are Wonderful, Herskovitz and Acco. South Africa exports more of its pomegranate (about 80%) than is consumed locally. Production and export volumes are increasing in last years. Nearly 55% of the export volume goes to European Union, about 10% to United Kingdom, more than 16% to Middle East, 10% to East Asia, 5% to Russia and 5% to other African countries (Phaleng and Lubinga, 2018).

China:
China mainly producing pomegranates for local markets. About 70% of the total production is sold in local markets. It was reported that they faced with nail problems during last years and the fruit prices raised due to the decrease in supply. A very sweet Tunisian variety is the most popular in China.

Egypt:
Most important varieties in Egypt are Baladi and Wonderful and the biggest markets for Egyptian pomegranates are currently Malaysia, Singapore, Russia, Ukraine and some European countries.

Tunisia:
Tunisia has an increase in the pomegranate production which makes it as an important player in the market. Tunisian pomegranates are known for their good quality, sweet flavor and small seeds. The season overlaps with Turkey and Egypt where the markets are more or less similar.

Afghanistan:
The country is among the origins of the pomegranate fruit and the production is always in place. Afghanistan is known to have more varieties of trees than any other countries. Country still has more production of pomegranate fruits but has serious problems in marketing, due to political issues. Main markets for Afghan pomegranates are in Dubai and Middle East.

Azerbaijan:
Pomegranate is a favorite fruit in Azerbaijan which is a symbol of Azerbaijani profusion. The climate is so suitable for growing pomegranates. Traditionally, pomegranates have been cultivated in almost every region of Azerbaijan. Pomegranates are often consumed as juice in Azerbaijan. It is known that both fresh and processed Azerbaijani pomegranates are available in the local and foreign markets, i.e. Russia, Ukraine and European countries.

Australia:
Australia, similar with Italy, is a new player in the market, where pomegranate was an unknown fruit several years ago. Both the production and consumption are increasing. Harvest starts mainly in March and extends till June. It was reported that the weather conditions are not ideal for growing pomegranates and the yield and quality is not reaching to expected levels. Australia also imports some pomegranates due to the low production.

Italy:
New plantations are started to be established in Italy, both in south and north of the country and the Puglia region. Production in south is reported to be used in fresh consumption (few exports to northern countries) and in the north for processing. Country also imports pomegranate fruits from India.

Pomegranate fruits known as healthy exotic crops and their consumption is increasing in all over the world, but mainly in European markets. Many of the above listed countries are exporting their products to European markets. In the ITC codes, pomegranates are included in the group of fresh fruit with a HS code of 0810907530. Pomegranates are the most important fruits in this group, but in reality the group includes fruits like cherimoya, barbary figs and medlars. When evaluating the date about this group, it can be concluded that the import data is doubled in last 5 years, where Israel has a stable export to Europe while turkey and Peru have an important increase. The imports to Europe is still expected to increase.

The main entrance point of the Europe is the Netherlands, due to being arrival point of the ships and the main destination of the pomegranate fruits is Germany. It was followed by other northern countries. The climatic conditions in northern European countries are not suitable for growing pomegranates and they rely on the importing. Rather than Germany, France, Italy and the United Kingdom are the other important importers of the pomegranates. The main inner exporter of the European Union is Spain. The values of import minus export is estimated to be around 60.000 tons in the last years (2016-2017). Since the re-naming of pomegranate fruits as “super fruit”, the ways of consumption of the fruit was expanded. The fruits are used to make juice, jams and value add into salads and desserts too. The pomegranate seed oil also gained importance in the food industry, mainly for personal care. Ready-to-eat arils and deep-frozen products are also becoming so popular in the international markets.
The main requirement for the European markets is the maximum residue levels (MRLs). The MRLs for the pomegranate, as well as for other crops can be followed from the EU MRL database, but some EU member states, i.e. United Kingdom, Germany and the Netherlands has some stricter rules than the general EU rules. According to EU standards, pomegranate fruits are classified as “Extra”, “Class I” and “Class II”. In all classes, subject to the special provisions for each class and the tolerances allowed, the

pomegranates must have some minimum requirements and must be (CBI, 2018):

- whole; (Fruits must not have any damage or injury spoiling the integrity of the produce. Slight defect in crown is permitted).
- sound; produce affected by rotting or deterioration such as to make it unfit for consumption is excluded; (Fruits must be free from disease. In some cases, fruits may be damaged by Heart rot or rotting without having external signals or very slight abnormal color but liable to make the produce unfit for consumption upon arrival at its destination, are to be excluded)
- clean, free of any visible foreign matter; (Fruits must be free of dust and chemical residue).
- free of pests and pest damages on the general appearance of the produce; (The presence of pests can detract from the commercial presentation and acceptance of the pomegranate).
- free of abnormal external moisture, excluding condensation following removal from cold storage; (This does not include moisture on produce following release from cool storage but applies to excessive moisture, i.e. free water lying inside the package).
- free of any foreign smell and/or taste; (in some cases, storing or transporting pomegranates with other fruits or products may cause them to absorb abnormal smells and/or tastes).
- free of damage caused by frost;
- free of damage caused by low and/or high temperatures;
- free of sunburns affecting the arils of the fruit (Sunburns might affect the arils color rather than outside. Arils color may be change from typical cultivar color to light or white color).

The highest import to Europe began in May, when the production is relying on the southern hemisphere. The wholesale prices before this peak goes around 1.0 to 1.8 €/kg, where it moves to about 1.80 to 3.40 €/kg in May. The mode of transport and the product quality are also affecting the prices. The quality is related with many external and internal conditions. Some important external conditions are: excess or less rainfall (cause of cracking) and high temperatures (cause of sunburn). The external factors are also affecting the pest populations and etc. but most of these are also in the internal factors, i.e.: pest management (introduction of Heart rot and Medfly), water deficit and water quality, wrong pruning practices, wrong fertilization, and etc. These are mainly related with the production of the "quality"; and there are some factors which are affection the protection of the "quality". The protection of the quality is related with the postharvest issues, where many researches had been conducted to help to protect the postharvest quality of pomegranate fruits.

Recent researches about production

Due to the increase in the demand for pomegranate fruits, there is an increase in the area of production too. However, human induced climate change is significantly influencing crop production in all over the earth mainly via water scarcity, extreme weather conditions and degradation in biodiversity. On the other hand, the human population is increasing, where the available land for crop production is stable or decreasing. Therefore, many of the new researches are focusing on the increasing yield. One of the ways for increasing the yield from a given area is using high-density planting system. In of the studies, Haneef et al. (2014) worked with cv. Bhagwa and test the growing high density of (2 m × 2 m); and reported that having high yield from the 4-years old trees is possible with correct irrigation, fertilization and pruning of the trees. In another study, Shanmugasundaram and Balakrishnamurthy (2017) reported that high density planting of cv. Mridula is possible and the fruit yield is increasing with the applications of three sprays of NAA 10 ppm + GA3 50. Bedding system was suggested by Marathe et al. (2017) in arid and semi-arid regions where they noted that bedding system provides necessary aeration in active root zone and increase nutrient uptake of pomegranate trees. Another important cultural practice for growing pomegranates is the pruning, which has a high influence on the tree yield. The pomegranate fruits are known to occur on short spurs which mostly appears on the 2-3 years old branches. Newly conducted studies reported that pruning of the braches to about 15-30 cm length provides higher yield in total per tree (Hiremath et al., 2018; Kabuli et al., 2018).

Irrigation and fertilization are also so crucial for increasing the yield. One of the newly conducted studies about fertilization reported by the Khattab et al. (2012) revealed that humic acid and amino acids plays an important role on the fruit yield of pomegranate cv. Manfalouty. Galindo et al. (2013) reported that trunk diameter with midday stem water potential (Ψ_{stem}) and midday leaf conductance (g_l) might be used to predict the exact water requirements and prepare effective irrigation schedules. Two interesting studies by Laribi et al. (2013) and Pena et al. (2013) reported that fruits of trees irrigated with sustained deficit irrigation (SDI) with 50% of ETc shows lower weight loss during storage. In a different study Parvizi et al. (2014) reported that irrigating alternate sides of trees with 50% of ET_C reduces the fruit yield while irrigating alternate sides of trees with 75% of ET_C increases the yield.

Problems of pests and diseases are also so crucial while they are causing reductions in yield and quality of the fruits. Aphids (*Aphis punicae*), Mediterranean fruit fly (*Ceratitis capitata*), pomegranate butterfly,

(*Deudorix* '*Virachola*' *livia*) and black heart (*Alternaria* spp.) are the most important problems of pomegranate orchards. A detailed study carried out by Kahramanoğlu and Usanmaz (2013) about most of these problems and reported some important suggestions about management of them. Authors suggested that Spirotetramat (as a systematic insecticide) provides good control of *P. citri*, while fruit thinning improves the efficiency of the insecticide by reducing the population of the pest. Researchers also noted that attract-and-kill traps (30 traps ha^{-1}) are effective in controlling *C. capitate* and two applications of Indoxacarb is effective in controlling *D. livia*. In another study, imidacloprid (1 µl ml^{-1}), thiacloprid (1 µl ml^{-1}) and thiamethoxam (0.35 µl ml^{-1}) were reported to be effective in controlling aphids (Rouhani et al., 2013). Farrokhzadeh et al. (2017) reported that *Binodoxys angelicae* (Haliday; Hymenoptra: Braconidae) and *Ephedrus persicae* (Frogatt; Hymenoptra: Braconidae) have potential to be used as biological control agents against aphids. Kambrekar et al. (2015) reported that Emamectin benzoate (90.83 g ha^{-1}) and spinosad (88.91 g ha^{-1}); and Nadaf (2017) noted that Chlorantraniliprole (0.15 mL L^{-1}) is a newly developed insecticide which might be used to control *D. livia*. For the control of Medfly, Pezhman (2016) recommended that cera-trap is an effective. One of the most important problems of pomegranate production is black heart or heart rot, caused mostly by *Alternaria alternata*. The affected fruits have no or slight symptoms on the fruit, but the inside of the fruits is all damaged and becomes rotted. Therefore, the marketing quality of the fruits decrease. The first appearance of *Alternata alternata* in pomegranate orchards observed after 2010 in some of the European countries [i.e. Cyprus (Kahramanoğlu et al., 2014), Spain (Berbegal et al., 2014), Italy (Faedda et al., 2015)]. Azole group fungicides (Tebuconazole and Propiconazole) were reported to be effective to inhibit the pathogen growth (Kumar et al., 2017).

Physiological disorders, i.e. sun scald and fruit cracking are common in pomegranate fruits. Sun scald and sunburn damage becomes severe when fruits are exposed to direct sunlight. Proper canopy management, application of kaolin and using some covering materials are known to prevent or reduce the incidence of sun burn (Kahramanoğlu and Usanmaz, 2016; Gündeşli et al., 2019). Ghorbani et al. (2015) reported that covering fruits with 18 or 22 holes 1 cm^{-2} covering materials provide about 50% reduction in sunburn. Meena et al. (2016) reported that red nets with shade levels of 35% or 50% PAR might provide better quality and prevent sunburn on fruits. On the other hand, fruit cracking was reported to reduce significantly with the application of 300 ppm pacloputrazol (Khalil et al., 2013). Foliar calcium fertilization in the form of a nano-Ca formulation (0.50 g Ca L^{-1}) or in the form of $CaCl_2$ (2.73 and 5.45 g Ca L^{-1}) were also reported to reduce fruit cracking in pomegranate (Davarpanah et al.,2013).

Recent Researches about Postharvest Handling

"Maintaining" the quality of the fresh pomegranates, is as important as the "production" of the quality. This is true for all type of produce, but so crucial for pomegranate fruits, because they are so susceptible to storage conditions. Long/wrong/inappropriate storage periods/conditions cause weight loss and reduction in the quality of the fresh produce. Other important problems associated with the postharvest handling of pomegranate fruits are chilling injury and decay. Until now, numerous researches carried out about the suitability of the conditions for storage of the pomegranate fruits and the results of these valuable studies suggest that 5-7 ºC and >90% relative humidity are required for the preservation of the quality of fresh pomegranate fruits (Elyatem and Kader 1984; Al-Mughrabi et al., 1995; Kazemi et al., 2013; Okatan et al., 2018). Temperature and relative humidity are very important for the 4 important biological process (respiration, transpiration, ethylene production and diseases) which accelerate deterioration of the fresh produce. The other important factor for the deterioration of the fresh produce is the atmospheric composition. The CO_2 level in the ambient conditions is about 0.03% where the O_2 is about 21.0%. Increasing the level of CO_2 and reducing O_2 are crucial for slowing respiration and preventing the occurrence of diseases. Thus, the atmospheric composition is also very important for the preservation of the quality of the fresh produce. Furthermore, modified atmosphere packaging (MAP) comes to forefront of important which is a dynamic process of altering gaseous composition inside a package. Special, nano-technological packaging materials are used to store the fresh produce where the material allows some exchanges of O_2 and CO_2 by reducing the O_2 level and increasing the CO_2 level inside the package (Farber et al., 2003, Mahajan et al., 2007, Caleb et al., 2012). It is reported by some Authors (Kader, 1995; Palou et al., 2007; Mirdehghan and Ghotbi, 2014) that MAP technology is successful for the prolongation of storage duration of pomegranate fruits up to 3 months while reducing weight loss and chilling injury; and preventing decay. Some methods were previously reported to alleviate or reduce the incidence of chilling injury, i.e. intermitted heating. Sayyari et al. (2016; 2017) reported that Methyl jasmonate and Salicyloyl chitosan can reduce chilling injury on pomegranate fruits. Application of black seed oil and propolis with or without modified atmosphere packaging reported to have significant effect on the prevention of weight loss, chilling injury and decay; and on the appearance quality of the fresh pomegranate fruits and can increase the storage duration of the fruits until 5 months (Kahramanoğlu et al., 2018; Korkmaz et al., 2016). Meighani et al.

(2015) reported that commercial resin and carnauba waxes have potential to lower the respiration rate of fresh pomegranate fruits and reduce weight loss. Fludioxonil was on the other hand reported by Palou et al. (2007) and Kahramanoğlu et al. (2018) to reduce the fruit decay caused by *Botrytis* sp. Quaglia et al. (2016) noted that olive-mill wastewater has potential to be used as alternative for the control of fungal pathogens of pomegranate fruit. On the other hand, some biological agents i.e. crab shell chitosan reported to have positive effects on the control of these pathogens (Munhuweyi et al., 2016; Munhuweyi et al., 2017). Combined application of chitosan with modified atmosphere packaging is reported to prevent weight loss and also control chilling injury (Candir et al., 2018).

Summary

Pomegranate fruit has a considerable increase in the demand; and the production area of this "super fruit" is continuously increasing. Due to the characteristics of the tree and extreme weather conditions all over the earth, the yield has been showing an increase while the total production is increasing, due to the increase in the total production area. Recent studies continue to confirm its medical uses and increase the consumption. Parallel to those studies, recent researches helps to solve the important problems of the pomegranate cultivation and postharvest handling, i.e. fruit cracking, sun burn, black heart, yield reduction due to water scarcity, quality loss during storage, and etc. However, current knowledge is not necessary to ensure the sustainability of the pomegranate sector and further studies needs to resolve the problems. The test and use of environmental friendly applications in the pomegranate sector is also increasing, which are promising trends in the sector. However, it is also important that some of the limitations imposed in the tree and fruit characteristics may need to be explored by pomegranate breeding. Breeding or selection of resistant varieties to above mentioned problems; and/or varieties producing fruits with higher demand in the market, are the key issues for the future of pomegranate sector.

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