Post Harvest Management of Pomegranate

National Research Centre on Pomegranate
Solapur-413 255 Maharashtra
(Indian Council of Agricultural Research)
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Dr. K. Dhinesh Babu
Dr. R.A. Marathe
Dr. V.T. Jadhav

National Research Centre on Pomegranate
Solapur-413 255 Maharashtra
(Indian Council of Agricultural Research)
National Research Centre on Pomegranate (ICAR) was established in 2005 for promoting the research on production, utilization and improvement of pomegranate fruit. Today, India is one of the leading producers of fruits in the world. Fruit crops are cultivated over 63.83 million ha with a total production of 748.78 million tones/annum and productivity of 11.7 t/ha. Unfortunately, about 25-40% of the total fruits produced in the country are lost every year. This is chiefly due to improper postharvest handling operations and this has resulted in wide gap between the gross production and net availability of fruits. This limits the quantum of fruits available for processing and export. During 2010-11, the pomegranate was cultivated over 1.07 lakh ha with a total production of 7.43 lakh tones and productivity of 6.9 t/ha in India. Reduction of postharvest losses will pave the way for export promotion and availability of more quantity of fresh fruits and processed products. Hence, it is required to pay much attention on various aspects of post harvest handling of pomegranate viz., harvesting, grading, packing, transport, storage etc. With this intention, this small book on “Post harvest management of pomegranate” is published by reviewing the existing literature.

K. DHINESH BABU
R.A. MARATHE
V.T. JADHAV

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Post Harvest Management of Pomegranate

Introduction

Pomegranate is an important fruit crop of arid and semiarid regions of the world. It is a highly remunerative crop for replacing subsistence farming and alleviating poverty. There has been a steady increase in area and production of pomegranate in the country. By 2025, the area under pomegranate would increase to 7.5 lakh ha from 1.25 lakh ha at present. Consequently, production is expected to increase by 10 fold and export by 6.97 fold by 2025. To achieve these targets coordinated and sustained efforts are required by all concerned with pomegranate research and development to develop scientific, profitable, eco-friendly and innovative technologies for cultivation, both in traditional as well as non-traditional areas (Jadhav and Sharma, 2007).

Pomegranate is a subtropical fruit crop grown in all parts of Maharashtra state. It contains higher protein percentage than other fruits and in minerals, it is as good as banana and guava and better than grape, mango, orange, papaya etc. It is one of the richest source of Riboflavin. Rind of the fruit, bark of stem and root contain more than 28% gallotannic acid and yellow dye is extensively used in tanning. Pomegranate can be grown on various soil types and being sturdy, it withstands drought (Anon., 1984).

By 2025, the area, production and export of pomegranate is expected to reach 7.5 lakh ha, 114 lakh tones and 83,800 tonnes respectively compared to 1.25 lakh ha, 11.4 lakh tones and 12,030 tonnes in 2005. At present, India processes hardly 2% of the total produce of pomegranate (Jadhav and Sharma, 2007). Hence, there is an urgent need to promote post-harvest and processing techniques.

Indian horticulture has made a rapid stride in last two decades maintaining the growth rate of 5-6 per cent. One of the significant developments witnessed during the period is that horticulture has moved from rural confine to commercial production and this changing scenario has encouraged private sector investment in production system management. Contribution of horticulture to agricultural GDP has increased to 29.5 per cent. Initiatives taken by Government and other
stakeholders have impacted the development in terms of increased production, productivity and availability of horticultural crops. Since the growing of horticultural crops is rewarding to the farmers in terms of returns per unit area, the sector is expected to contribute significantly for food and nutritional security, employment opportunity and poverty alleviation. In horticulture, the reduction of postharvest losses and value addition has received a centre stage in prioritization of research progress (Singh, 2009).

Pomegranate, a native of Iran, although its wild forms were found in India, Afghanistan and Syria, was domesticated in 2000 BC and adapted to the Mediterranean regions of Central Asia, Africa and Europe. The cultivation of pomegranate was not undertaken on commercial scale except for a few pockets like Alandi and Purander of Pune district (Anon., 1984). Currently, pomegranate is grown in most parts of tropical and subtropical countries and it has become boon for Indian farmers in arid region although it was considered as a minor fruit till 1986. Maharashtra, Karnataka, Andhra Pradesh, Gujarat, Tamil Nadu, Rajasthan and Punjab are the states where cultivation has gained momentum. There are more than 25 pomegranate varieties grown in different parts of India. Bhagwa and Ganesh occupy the major area under cultivation in India. Pomegranate is a subtropical fruit crop grown in all parts of Maharashtra state (Anon, 1984). Today, in India, Maharashtra state is considered as 'pomegranate basket of India' contributing more than 70% of the total area under pomegranate followed by Karnataka and Andhra Pradesh. Besides, Bhagwa and Ganesh, the other cultivars grown by farmers include Mridula and Phule Arakta. Largely, it is cultivated in marginal land with fertigation system and bahar treatment for regulating flowering and fruiting. Although these parts, where pomegranate has become commercial crop do not have Mediterranean climate, the technological manipulation has made it highly adaptable. Thus, we have to think more for technologies which could help in addressing the challenges of future, with respect to change in climate. The cultivation of pomegranate, once isolated in few pockets of the country, can be now done in Punjab like situations. With the efforts of scientists of Central Institute of Post harvest Engineering and Technology (CIPHET), pomegranate cultivation is
being done significantly in Punjab, Rajasthan and Haryana. There is need to
develop the region-specific pomegranate production technologies suitable for
various tropical and subtropical parts of the country (Asrey, et al. 2007). Profits
upto 1.5 lakh/ha/annum have been demonstrated by some growers. It is therefore,
highly remunerative crop for replacing subsistence farming. It is an ideal crop for
sustainability of small holdings, as pomegranate is well suited to topography and
agroclimate of arid and semiarid regions (Jadhav and Sharma, 2007).

**Antiquity**

The pomegranate has been cultivated as a fruit crop since antiquity. The
usage of pomegranate is deeply embedded in human history with references in
many ancient cultures of its use in food and medicine (Holland et al., 2009).

Pomegranate is known by different vernacular names in various languages
(Deshpande, 2008) such as,

- Sanskrit : Dadima, Dantabiya, Dantabijak, Karak, Lohit Pushpam
- Bangla : Dalim, Dadim
- Gujarati : Dadam, Dadiyam
- Hindi : Anar, Dalim, Dadim
- Kanada : Dalimba, Daalimbae
- Malayalam : Mathalam
- Marathi : Dalimb
- Tamil : Madulai, Madhulai
- Telugu : Danimma, Daalimma, Danimmapandu

The pomegranate, botanically known as 'Punica granatum L.' belongs to
the family Punicaceae and has only 2 species. viz., *Punica granatum* and *Punica
protopunica*. The species, *P. granatum* is divided in to 2 sub-species viz.,
chlorocarpa and porphyrocarpa. *Punica protopunica* is wild in nature.
Pomegranate (*Punica granatum* L.) has the somatic chromosomes 16 or 18
(Darlington and Janakiammal, 1945).

Eg.: 2n=2x=16 : Bhagwa, Ganesh, Ruby, Jalore Seedless
     2n=2x=18 : Double Flower, Vellodu
Pomegranate is believed to be originated from Iran. Iran is considered as the 'Primary centre of origin' for pomegranate. Besides Iran, Pomegranate is available in Afghanistan, Pakistan and India. These countries are considered as the 'Secondary centres of origin'. The cultivation of pomegranate is sprawling over the Mediterranean countries. In nature, it grows wild in western Himalayan regions of India (Himachal Pradesh, Jammu & Kashmir and Uttarakhand) and Pakistan. It is one of the oldest known edible fruits and is associated with ancient civilizations of the Middle East. From its origin in the area now occupied by Iran and Afghanistan, the pomegranate spread east to India and China and west to Mediterranean countries (Turkey, Egypt, Tunisia, Morocco, and Spain). Spanish missionaries brought the pomegranate to the Americas in the 1500s (Hodgson, 1917; La Rue, 1980).

The primary commercial pomegranate growing regions of the world are the Near East India and surrounding countries, and southern Europe. Nearly all production in the U.S. is centered in the southern San Joaquin Valley of California, with about 4000 hectares of pomegranates (predominately of the “Wonderful” variety). The fruit is consumed fresh or processed into juice, syrup, jams, or wine (Kumar, 1990; Adsule and Patil, 1995). Pomegranate is one of the five ancient edible fruits known to mankind viz., fig, date, olive, grape, and pomegranate. Pomegranate (Punica granatum L.) is an important fruit crop of arid and semiarid regions of the world. The pomegranate is an ancient plant cultivated in the subtropical zone which is monotypic in nature with only one genus (Levin, 2006). The tree is deciduous in the areas of low temperature during winter but under tropical and subtropical conditions, it is evergreen or partially deciduous depending upon the variety / genotypes. It grows very well and produces better crop in the semi arid climate where cold winter and hot summer prevails. The tree requires hot and dry climate during the period of fruit development and ripening. The fruits are mainly used for dessert purpose, has healthful dietic value also. It grows under a variety of climatic conditions, from sea level upto 1800m (Tajuddin and Prakash, 1996).

**Salient features**

Pomegranate has emerged as an important fruit crop of arid and semiarid regions due to the salient characteristic features viz.,
• Ability to withstand harsh and hostile climate  
• Built-in capacity to withstand heat, drought and moisture deficit (Jalikop and Sampathkumar, 2000)  
• Suitability to marginal lands and gravelly soils  
• Capable of growing even in shallow soils  
• Ability to withstand salinity to some extent  
• Higher remuneration with low cost of cultivation  
• Ability of fruits to withstand long distance transport  
• Good keeping quality of the fruits &  
• Immense medicinal value of the fruit and plant

Thus, it has become an excellent choice for the arid and semi-arid conditions and has got great scope in India (Chundawat, 1990). Although the tree can withstand frost, it is injured by temperatures below -11ºC (Singh, 1980). It grows up to an altitude of 1600m -1800m above msl. (Tajuddin and Prakash, 1996). Pomegranate (Punica granatum) can be grown successfully in arid regions where life saving irrigation facilities are available (Awasthi et al., 2007).

**Utility**

The edible portion of pomegranate is the acidic pulp, known be 'arils' (Purseglove, 1968) which are nothing but the juicy sacs encasing the soft seeds. The juicy outgrowth of the seed is called the aril (Singh and Saxena, 1969). The fruit is consumed fresh (table purpose) or utilized as processed products viz., juice, syrup, minimally processed arils, anardana, jam, jelly, wine, carbonated beverage etc.

In India, pomegranate is cultivated over 1.2 lakh ha area and India is the leading producer of pomegranate in the world. But, this abundance of production is not fully utilized and about 20-30% of it is wasted due to spoilage. There are two post harvest approaches to overcome this problem.

One is the creation of cold storage or cool chain facilities both at production (growing belts) and consumption regions (urban centres) to ensure supply of fresh fruits throughout the year.
Alternately, the fruits can be processed and preserved for a long time with benefit of value addition. The country has very limited cold-storage facilities, for storage of approximately 19 million tonnes food products.

The high cost and variation in the quality of raw material and inadequate and expensive cold storage facilities for storage and transport and distribution of raw as well as processed products are the major constraints in the processing sector. Keeping in view the vast scope of expansion of pomegranate processing industry in India, there is an urgent need of developing packing stations with facilities for sorting, grading and processing. For export, world class cool chain, precooling units, grading and packaging units, cold storage in production and exit points and refrigerated transport are essential to compete in exports with the rest of the world.

The better purchasing power with increased per capita income and increased consumer awareness towards quality and hygiene aspects of the food also brightens the scope for processing sector. Hence, appropriate post harvest management and valorization of agri-horticultural produce play a crucial role in the growth of food processing sector in India.

- Pomegranate is very much liked for its cool, refreshing juice with sweet acidic taste and also for its medicinal properties viz.,

- The pomegranate fruit is rich in beneficial antioxidants, like polyphenols, tannins and anthocyanins. The antioxidant level of pomegranate juice is higher than in other fruit juices, red wine or green tea. It is also a good source of vitamins C and B, antioxidant polyphenols, pantothenic acid and potassium.

- The pomegranates can help fight osteoarthritis, as regular consumption of the juice always reduces down the corrosion of the cartilage (Lansky and Newman, 2007)

- Pomegranate juice is believed to increase blood flow to the heart, and is extremely beneficial for people with ischemic heart disease and some other diseases (Seeram et al., 2006). It is effective in curing atherosclerosis and cardiovascular disease (Holland et al., 2009).
- The juice of the fruit also has **antiviral and antibacterial effects against dental plaque**. Consumption of pomegranate juice has proven to help hugely in cases of **prostate cancer** or prostatic hyperplasia, diabetes or lymphoma (Basu and Penugonda, 2008).
- Pomegranate juice has also shown to reduce systolic blood pressure by inhibiting serum of angiotensin-converting enzyme. The juice is useful for patients suffering from leprosy.
- Citric acid and sodium citrate are manufactured from the juice of pomegranate in Azerbaijan.
- Its barks and rinds are commonly used in dysentery and diarrhoea.
- The rind is also used as dyeing material for cloth. The flowers yield red dye which is used for dyeing cloth (Singh, 1995).
- Tannin is obtained from fruit rind, stem and root bark and leaves (Bose, 1994).
Pomegranate Fruit

Botanically, the fruit of pomegranate is known as 'Balusta' which is a modified berry. Out of male, intermediate and bisexual flowers, the fruit develops from the inferior ovary of the hermaphrodite (bisexual) flowers usually. Shulman et al. (1984) observed that the fertile flowers were vase-shaped and developed fruits, while bell shaped flowers contained few egg cells and were sterile. The ovary is normally three celled below with axial placentae and six celled above with parietal placentae but has one style and stigma (fig. 1).

The persistent leathery calyx of the flower with numerous stamens inside adorns the fruit as its crown after the fruit set.

The pomegranate fruit develops from the flowers which are most commonly red to red-orange and are funnel shaped, although double and variegated flowers are found in some ornamental selections, which are not grown for fruit. Pomegranate can be self pollinated or cross pollinated by insects (Morton, 1987). Flowers are primarily borne sub terminally, primarily on short lateral branches older than one year (El-Kassas et al., 1998), although some cultivars flower on spurs. Flowers occur as single blossoms or in clusters. Pollination occurs by insects – hummingbirds. Stigma receptivity last 2 to 3 days and declines quickly in unpollinated flowers (Melgarejo et al., 2000). Pomegranate flowers are heterostylos. Long styled perfect flowers are larger, have larger ovaries, and set more fruit than short style types, which are either intermediate or functionally male only. The proportion of the flower types varies among cultivars and year to year (Martinez et al., 2000).

The fruit is berry-like with a leathery rind (or husk) enclosing many seeds surrounded by the juicy arils, which comprise the edible portion of the fruit (Watson and Dallwitz, 1992). The aril juice sack is composed of many epidermal cells. According to cultivar, arils range from deep red to virtually colourless, whereas the enclosed seed varies in content of sclerenchyma tissue, which affects seed softness. The number of locules and arils (and enclosed seeds) varies, but may be as high as 1300 per fruit (Levin, 2006).
The fruit has a prominent calyx, which is maintained to maturity and is a distinctive feature of the pomegranate fruit. The husk is comprised of two parts: the pericarp, which provides a cuticle layer and fibrous mat; and the mesocarp (known also as the albedo) which is the spongy tissue and inner fruit wall where the arils attach. Septal membranes are the papery tissue that further compartmentalizes groups of arils, but arils are not attached to this tissue.

**Morphological Characteristics**

The pomegranate fruit is almost round, varying in diameter from about 6.25 to 12.5 cm (2.5 to 5 inches) with a prominent and persistent calyx and a hard, leathery skin (rind or husk). Skin color varies from yellow overlaid with light or dark pink to bright red, depending on variety (Patil and Karale, 1984; Roy and Waskar, 1997). Botanically, the pomegranate is classified as a berry, but the edible portion develops not from the seedbox wall but from the outer seedcoat. The edible part is the pulp (aril) surrounding the seeds. The pulp, together with the locular septa (membranous walls and white, spongy tissues), represent the whole pericarp (fig.2). The arils are filled with juicy red, pink, or whitish (depending on variety) pulp. In each aril (juice sac) there is one angular, soft or hard seed. Although the fruit's leathery skin appears to provide protection from physical damage and water loss, this is not the case. The skin can easily be scuffed from abrasions and has many microcracks and other openings that facilitate water loss. Thus, pomegranates should be handled with as much care as apples during harvesting and postharvest handling.

**Fruit composition**

The pomegranate is commercially grown for its sweet acidic fruits, which are mainly used for dessert purposes. The rind of the fruit is rich in tannins and is used as a valuable tanning material. The flowers yield red dyes. The fruit is also found in abundance in wild form in the north western Himalayas. The wild pomegranate fruit is filled with angular hard seeds covered with a juicy, pink or yellowish white, sweet astringent acid pulp. The fruit is used by sun drying the
seeds along with the pulp, which constitute the product anardana, a valuable commodity used as a condiment and for other culinary purposes. Methods have been standardized for the commercial exploitation of anardana (Bhatia and Sarin, 1979). The seeds have oestrogenic acitivity due to the presence of 1.00 mg oestrone and 0.036 mg courestrol (a nonsteroidal oestrogen) per 100g of seeds (Moheam et al., 1988). The edible portion is the bright red pulp surrounding the individual seeds (Ryall and Pentzer, 1974).

Gil et al (1995) found that six anthocyanin pigments are responsible for the red colour of pomegranates, and identified them as delphinidin-3 glucoside and -3,5 diglucoside, cyanidin-3 glucoside and -3,5 diglucoside, pelargonidin -3 glucoside and -3,5 diglucoside. Generally, there was an increase in juice pigmentation with fruit ripening. The concentration of pigments in juice obtained from matured fruits ranged from 50 to 100µg anthocyanin per gram of aril (fresh weight). The total amount of pigment in the juice was generally less in fruits with reddish skin than in those with yellow skin (Gil et al., 1995). The presence of natural pigment 'anthocyanins' offers attractive red colour to the rind (skin), aril (the outgrowth of seeds/juicy sacs encasing the seeds) and juice of the fruit.

Pomegranates are rich in polyphenols specifically ellagic acid and punicalgins, both of which can act as potent antioxidants. Ellagic acid is found in the red arils (seeds) of the pomegranate. Punicalgins are found only in the outer skin of the pomegranate, and are estimated to have twice the antioxidant capability of red wine and green tea as reported by Sevda and Rodrigues (2011).

Fruits ripen about 6 to 7 months after flowering (Morton, 1987) and are harvested when qualities are deemed most appropriate for expected market use. In Israel, the wonderful variety is harvested when the TSS reaches 15% (Morton, 1987). Minimum maturity for Wonderful in California is based on titrable acidity less than 1.85% and color darker than an established reference (Kader, 2006). The principal acids present in the pomegranate is malic and citric acid (Legua et al., 2000).

The fruits contain 45-61% juice on whole fruit basis or 76-85.5% in relation to the weight of arils (Veres, 1976). The juice has 12-16% sugar,
consisting mainly of glucose or fructose (Nerd, 1965; Lee et al., 1974); citric and malic acids have been identified as the predominant acids in fruits (Ulrich, 1970; Lee et al. 1974). The fruit rind contained large amount of excessively astringent tannin, which made the juice unpalatable if the whole fruit is crushed or pressed at high pressure (Camengo et al., 1988).

Unlike most horticultural fruits, inherent seed dispersal is not achieved through consumption of all or most of the fruit and seeds with accompanying spread. Rather, the pomegranate fruit structure has apparently evolved to ensure splitting of the leathery husk, and exposure of the tempting arils and seeds (Morton, 1987) to the many happily cooperative birds and so forth serving as dispersal agents.

“Wonderful,” the most widely grown pomegranate variety in California, has a deep purple-red skin color with a glossy appearance. The arils and juice are a deep crimson color with good flavor due to high contents of sugars acids (Adsule and Patil, 1995), seeds are small and tender, and the rind is of medium thickness (Kader at al., 1984). In general, varieties that have whitish or pinkish arils (such as the “Mollar” grown in Spain) are usually sweeter than those with purplish or dark crimson arils because the latter varieties contain higher concentrations of organic acids (Gil et al., 1996). The edible portion (arils) of pomegranate is about 55-60% of total fruit weight and consists of about 75-85% juice and 15-25% seeds (Al-Ma’m and Ahmad, 2002; Lee et al., 1974).

Citric acid is the predominant organic acid, and titrable acidity ranges from 1 to 2% on fresh weight basis (Kader at al., 1984). Glucose and fructose are the titrable acidity decreases and soluble solids (mainly sugars) content pH, and red color intensity of the juice increase with pomegranate fruit maturation and ripening (Elyatem and Kader, 1984). For example, California-rown “Wonderful” pomegranates picked in mid-October had an average soluble solids content of 18.1% and a titrable acidity of 1.58%, whereas those harvested in late September averaged 17 and 1.8% respectively (Kader et al., 1984). There was no consistent relationship between the extent of red coloration of the skin and red color intensity of the arils. Differences in soluble solids, juice color, percent edible portion, and
percent extractable juice were small among fruits of various sizes. Large fruits (more than 250 grams) were generally lower in titrable acidity than smaller fruits (Kader et al., 1984).

The fruit attributes and compositional changes were evaluated in Wonderful pomegranate fruits of different sizes. It is found that fruit volume, fruit weight, and total aril weight are closely correlated. Any single character can be used as a common indicator of fruit size. The number of arils per fruit was highly correlated with fruit size with larger fruit containing greater numbers of arils. This is in contrast to average aril weight, which had no significant relationship to fruit size. Limitations in final fruit size could result from poor ovule development, insufficient pollination or inadequate fertilization (Wetzstein et al., 2011).

Akbarpour et al., (2009) reported that twelve pomegranate cultivars obtained from different growing regions of Iran were analyzed for their physical and chemical properties. These properties included fruit fresh weight, volume and density, peel thickness, soluble solids, titrable acidity, EC, pH, vitamin C, ellagic acid, content of juice and peel, total antioxidant activity of peel and juice etc. The total antioxidant activity measured by FRAP assay with a range of 225.17-705.50 (mmol/100g) and 157.33-419.33 (mmol/100ml) in peel and juice respectively.

Poyrazoglu et al (2002) reported that organic acids such as citric, L-malic, tartaric, oxalic, quinic and succinic acids were individually detected and quantified. Citric acid was the predominant (4.8 ±2.8g/lit) followed by L-malic acid. Tartaric, oxalic, quinic and succinic acids ranged between 0.28-2.83, 0.02-6.72, 0.00-0.82 and 0.00-1.54g/litre respectively. Phenolic compounds identified in freshly prepared pomegranate juices were gallic acid, protocatechuic acid, chlorogenic acid, caffeic acid, ferulic acid, o- and p-coumaric acids, catechin, phloridzin and quercetin.
Flowering tree

3 kinds of flowers

Fruit

L.S. of Fruit

Fig. 1: Flowers and Fruit of pomegranate
Fig. 2: Cluster bearing in pomegranate
Fruity Maturity

The pomegranate fruit reaches full maturity (ripeness) within 4.5 to 6 months after bloom, depending on climatic conditions (Lee et al., 1974). The fruits should be harvested before they become overripe and crack (split) open, especially under rainy conditions. Maturity indices are variety dependent and include external skin color (changes from yellow to red) and juice color, acidity, and soluble solids content (Ben-Arie et al., 1984). The maximum titratable acidity may be 1% in sweet varieties and 1.5 to 2% in sweet-sour varieties. Minimum soluble solids vary from 15 to 17%. The minimum maturity indices for California-grown “Wonderful” pomegranates are red juice color equal to or darker than Munsel color chart 5R-5/12 and titratable acidity below 1.85% (Elyatem and Kader, 1984).

The growth of Mule's Head pomegranate followed a single sigmoid curve whereas in cv. Wonderful, the growth was more linear. Mule's Head is an early variety whereas Wonderful is a late variety. From the pattern of CO₂ and ethylene production rate, pomegranate fruits are judged to be non-climacteric fruits (Elyatem and Kader, 1984; Shulman et al., 1984) and thus, maturation and ripening should take place on the plant before harvest to get quality fruits. The red colour of pomegranate peel and juice is due to presence of anthocyanins (Nerd, 1965; Harborne, 1967). The most common anthocyanin in the juice is delphinidin 3,5 diglucoside (Du et al., 1975).

- Ripening of pomegranate fruit occurs when the fruit is attached to the tree
- The fruits do not continue to ripe after harvesting from the tree, due to its non-climacteric nature
- Those fruits which attained maturity in the tree should be chosen for harvesting
- The quality of the mature fruits improves slightly during storage
- Sometimes, farmers have a tendency to practice early harvest to overcome the fruit cracking problem in mature fruits (caused by sudden fluctuation in soil moisture, prolonged dry spell followed by a heavy rainfall)
Avoid resorting to early harvest as it paves the way for poor quality of fruits.

There are certain parameters which reveal some clue on the maturity of the fruits, popularly known as 'maturity indices'.

Maturity Indices

The pomegranate fruits are harvested only after attaining maturity in the tree, i.e., the ripening phase is completed on the plant itself. The fruits are ready for harvest in 135-170 days after appearance of blossom. In summer, the fruit colour changes to dark yellow and dark red at maturity in winter. The fruit gives a metallic sound when tapped. The buds at the anterior end of the fruit get curved inside and become hard and dry at maturity. Properly mature fruits are easily scratched with finger nails. Early harvesting in order to avoid cracking is one of the causes of poor quality of pomegranate in India (Hayes, 1953).

- Colour of fruit: Harvesting is done at semiripe stage when the skin attains its characteristic colour (Reddish- Bhagwa, Ruby, Arakta, Mridula, Yellowish-Ganesh) with waxy shining surface.
- Shape of crown & fruit: The bud at the anterior end of the fruit gets curved inside and become hard and dry at maturity. The fruit shape becomes compact.
- Sound upon tapping: The fruit gives a metallic sound when tapped.
- Scratch: Properly mature fruits are easily scratched with finger nails.
- Maturity period: The fruits become ready for harvest in 135-175 days after anthesis.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Variety</th>
<th>Maturity period (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bhagwa</td>
<td>175 DAA (170-180 days)</td>
</tr>
<tr>
<td>2</td>
<td>Ruby</td>
<td>170 DAA (165-175 days)</td>
</tr>
<tr>
<td>3</td>
<td>Ganesh</td>
<td>150 DAA (145-155 days)</td>
</tr>
<tr>
<td>4</td>
<td>G-137</td>
<td>148 DAA (145-150 days)</td>
</tr>
<tr>
<td>5</td>
<td>Jalore Seedless</td>
<td>140 DAA (138-143 days)</td>
</tr>
<tr>
<td>6</td>
<td>Arakta</td>
<td>135 DAA (130-140 days)</td>
</tr>
<tr>
<td>7</td>
<td>Mridula</td>
<td>135 DAA (130-140 days)</td>
</tr>
</tbody>
</table>
- Aril colour: The arils attain deep intensity of colour (Dark red- Bhagwa, Pink-Ganesh) with high juice recovery
- Colour of juice: Red colour of juice in Bhagwa, Arakta, Mridula, Ruby; Pink colour of juice in Ganesh;
- TSS: 13-16.5 ºBrix
- Titrable acidity: Below 0.8 %
- TSS/acid ratio: 25-40 (TSS/acid ratio is one of the most reliable maturity indicator)

The fruits are ready for harvest between 135 and 170 days after anthesis. Fruits are harvested when the skin turns slightly yellow and the fruit give a metallic sound when tapped (Adsule and Patil, 1995). At maturity, the fruit colour changes in summer to dark yellow and in winter to dark red. The buds at the anterior end of the fruit curve inwards and become hard and dry at maturity. Properly matured fruits are easily scratched with a fingernail. The fruit is generally clipped from the tree when ripe, and its quality improves on storing. Early harvesting in order to avoid cracking is one of the causes of poor quality of pomegranate in India (Hayes, 1953).

Depending on the Bahar treatments, pomegranate comes to harvest in installments. Usually the harvest commences in December / January and extends upto June / July. Crops ripening from April to June often get sunscorch or sunburn, and may also crack if rains intervene or irrigation is irregular (Venkatratnam, 1988). Ben-Arie et al., (1984) reported that pomegranate cv. Wonderful fruit reached horticultural maturity for commercial harvest when the total soluble slicks (TSS) content attained a fairly constant level of TSS content or titrable acidity at 20°C, but redness of the juice continued to increase upto and after harvest.

Shulman et al., (1984) studied the development of pomegranate fruit under continental (Bet Shean Valley) and moderate maritime (coastal plain) climatic conditions. They observed that fertile flowers were vase-shaped and developed fruits, while bell shaped flowers contained few egg cells and were sterile. Gibberellic acid induced the sterile flowers to develop into small fruits; However, these were devoid of juicy seeds. The growth of 'Mule's Head' pomegranate
followed a single sigmoid curve, where as in cv. Wonderful the growth was more linear. The seeds accounted for about half of the fruit weight. The edible juicy tissue of the seeds grew continuously from June to October, whereas the internal stone tissue ceased growing and hardened by the end of June. Juice, TSS and anthocyanin content of fruit increased continuously during maturation, while acidity decreased. Fruits of cv. Mule's Head” ripen early and have a low acid content, whereas fruits of the late ripening cv. Wonderful have high juice, TSS, acids and anthocyanins and are therefore suitable for processing. In both cultivars, fruit colour developed gradually and served as a criterion for picking. The stage at which 70-90% of the skin is red usually corresponds with a TSS:acid ratio suitable for commercial picking. Some cultivars, such as “Malissi” do not develop any red colour in the skin, however (Shulman et al., 1984).

The red colour of pomegranate peel and juice is due to presence of anthocyanins (Nerd, 1965; Harborne, 1967). The most common anthocyanin is the juice is delphinidin-3,5-diglucoside (Du et al., 1975), but cyanidin -3- glucoside, cyanidin – 3,5 diglucoside and delphinidin-3-glucoside were also noted (Krieventsov and Arendt, 1981). The fruit rind contained large amounts of excessively astringent tannin, which made the juice unpalatable if the whole fruit is crushed or pressed at high pressure (Cameroglu et al., 1988) the fruits contain 45-61% juice calculated on a whole fruit basis, or 76-85.5% in relation to the weight or arils (Veres, 1976). The juice has 12-16% sugar, consisting mainly of glucose or fructose (Nerd, 1965; Lee et al., 1974); citric and malic acids have been identified as the predominant acids in fruits (Nerd, 1965; Ulrich, 1970; Lee et al., 1974).

**Quality Indices**

- Pomegranate fruit quality depends on the following indices:
- Freedom from internal and external decay.
- Freedom from preharvest defects (such as cracking/splitting and sun-burn (Melgarejo, 2004) which cause dark brown to black discoloration of the affected skin area) and defects that may occur during harvesting and handling (such as surface abrasions, cuts, and impact bruising).
Skin color and smoothness.

Aril color intensity and uniformity

Fruit size may be considered a quality index, depending on the intended use of the pomegranates.

Flavor depends on sugar/acid ratio, which varies among cultivars. Soluble solids contents above 17% and total phenolics contents below 0.25% are desirable for optimal levels of sweetness and astringency, respectively (Kader et al., 1984).

Pomegranate does not ripen off the tree and should be picked up when fully ripe to ensure their best flavor. The key indicators of maturity are,

- The fruits are harvested in about 120-180 days from date of flowering.
- The side of the globular fruits flattens,
- Waxy shiny surface appears,
- When pressing the fruit (shell) with thumb, it creates a cracking sound,
- The calyx end completely dry,
- More juicy pulp,
- Intensity of red color of the juice,
- Intensity of red color turns purplish as the ripening extends in the plant.
- The aril to fruit ratio range from 0.56 to 0.72.

Paper bagging of fruits

- Sunscald, uneven colour development of fruits and aril paleness during summer are some of the problems reducing the marketability of fruits.
- Bagging the developing fruits 3 months before harvest helps to overcome these problems.
- Butter paper, white color cellulose based bags or zipped polyethylene bag (15x15cm) are suitable for bagging.
- Bagging is done on a bright sunny day when there is no moisture deposition around the fruits.
- White colour bags reflect sunlight and reduce the temperature around developing fruits.
- The optimal temperature helps in biosynthesis of anthocyanin pigments and prevents their denaturation during hot months.
- About 10-12% higher anthocyanin is available in the arils of bagged fruits, compared to unbagged fruits.

Padmavathamma and Hulamani (1996) conducted an experiment with fruit bagging using colored polyethylene bags. The highest average fruit weight was recorded with green bags (338.8g) and fruit diameter with red bags (8.31cm). Bagging did not influence fruit physical and chemical parameters significantly except for the total sugars which varied significantly with bag colour. Pink fruit colour was obtained with transparent bags and with no bagging (exposed fruits) whereas fruits under coloured bags were light green in colour.
Harvesting & Yield

**Harvesting**

The fruits are ready for harvest between 135 and 170 days after anthesis. Fruits are harvested when the skin turns slightly yellow and the fruit gives a metallic sound when tapped (Adsule and Patil, 1995). At maturity, the fruit colour changes in summer to dark yellow and in winter to dark red. The buds at the anterior end of the fruit curve inwards and become hard and dry at maturity (fig. 3). Properly matured fruits are easily scratched with a fingernail. The fruit is generally clipped from the tree when ripe, and its quality improves on storing. Early harvesting in order to avoid cracking is one of the causes of poor quality of pomegranate in India (Hayes, 1953).

Crops ripening from April to June often get sunscorch or sunburn, and may also crack if rains intervene or irrigation is irregular (Venkatratnam, 1988). Ben-Arie et al., (1984) reported that pomegranate cv. Wonderful fruit reached horticultural maturity for commercial harvest when the total soluble solids (TSS) content attained a fairly constant level of TSS content or titrable acidity at 20°C, but redness of the juice continued to increase up to and after harvest.

Pomegranate tree sometimes has a tendency to split open the fully ripe fruits as it is the natural means of seed release and dispersal. Resorting to early harvest to mitigate fruit cracking at maturity leads to poor quality of pomegranate in India. Late harvesting of fruits results in a physiological disorder known as internal breakdown, i.e. the discoloration of affected arils from that of rest of the arils. Hence, harvesting should be done at appropriate time. The fruits of pomegranate fruits are harvested only after attaining maturity in the tree.

- Harvest only the mature fruits (ie. semiripe- ripe stage) as it is not possible to ripen the fruits once they are plucked immature even with ethylene treatment.
- Early morning or evening hours is the most suitable time for harvesting as the fruits are susceptible to moisture loss.
- The fruits should not be pulled from branches.
• Make use of sterile scissors/ clippers for picking (clean with wet cloth & dip in 1% sodium hypochlorite for sterilization).
• Slash the stem close to the base of the fruits to overcome the damage of other fruits.
• Exercise care not to inflict any injury to the rind during harvest.
• Pay attention to harvest the fruits intact with crown.
• Climb the ladders / tripod stands to harvest the fruits from upright branches.
• Collect the fruits in plastic crates of 20 kg capacity washed with detergent.
• Don't heap too many layers of fruits in crates.
• Place the cushioning material at the bottom of the crates viz., dries grass, paddy straw or paper.
• Stack the fruits in shade and not in open sun as it leads to rind roughening.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Bahar</th>
<th>Flowering</th>
<th>Harvesting period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ambe</td>
<td>Jan-Feb</td>
<td>July-Aug</td>
</tr>
<tr>
<td>2</td>
<td>Mrig</td>
<td>June-July</td>
<td>Dec-Jan</td>
</tr>
<tr>
<td>3</td>
<td>Hasth</td>
<td>Sep-Oct</td>
<td>Mar-Apr</td>
</tr>
</tbody>
</table>

Yield
• The juvenile period of pomegranate is relatively low compared to other tree fruits crops.
• Though the tree starts bearing from 2\textsuperscript{nd} year onwards, it's advisable to nib off the flowers and allows flowering and fruitset only from 3\textsuperscript{rd} year onwards so that the vigour of the tree is restored.
• Curtailing the number of fruits / tree to its optimum level according to the age of trees upto 5 years and thinning the excess fruits helps to reap good quality fruits.
• Yield increases progressively and in the 10\textsuperscript{th} year, a tree may produce 175-200 fruits per year. (Waskar, 2008)
• Overbearing of the tree often results in breaking of branches.
• Economic yield of orchard is obtained upto an age of 17-20 years and under good management condition upto 25 years (Waskar, 2008)
Fig. 3: Bearing in established pomegranate tree
Export

Quality requirements for export

In European and other foreign countries, the demand is high for brilliant shiny crimson or red colour of fruits and sparkling red colour of arils (Sheikh, 2006). This is because whole fruits are widely used for decoration and arils are used for garnishing desserts and salads. Also juice from dark red arils is used for syrup making which is further used for flavoring mixed drinks, topping of ice cream and desserts. Therefore, desirable fruit characters for export to European and other foreign countries include

- **Fruit colour**: Shining dark red/rose pink colour of the fruit
- **Aril colour**: Dark rose pink arils
- **Mellowness**: Softness of seeds (arils)
- **Fruit weight**: Fruit weight around 200-400g
- **Fruit shape**: Round shape of individual fruit
- **Uniformity**: Uniform size and shape of the fruits in a package/pack
- **Appearance**: Freedom from scars, blemishes, scratches, rusting, rough surface, disease spots and fruit borer
- **Intact calyx**: Bracts of calyx having freshness and without any damage
- **Stem end**: Smooth cut at the stem end
- **Aroma**: Pleasant flavour and aroma
- **TSS**: High TSS (around 16-17 °B)
- **Disorder**: Fruits free from complaint of internal breakdown/aril blackening

Export potential

Considering the high keeping quality and availability throughout the year, India has great potential for export of pomegranate fruit. The commercial varieties Ganesh, Bhagwa and Phule Arakta are quite superior in quality and suitable for
export market. (Waskar et al., 2003). Some gulf countries like Sauri Arabia, Qatar and Kuwait and Bangladesh are the major importing countries of Indian pomegranate. During the year 1992-93, a total quantity of 17,903 metric tones of fruit worth at Rs. 215.60 lakh was exported from India (Waskar, 1997). However, the export of pomegranate increased to 25,000 metric tones in the year 2006 (Patil and Waskar, 2008). Afterwards, the export has crossed the mark of 35,000 tonnes per annum.

Jugale et al (2000) reported on Kolhe committee's recommendations for the improvement of the export trend of fruits in Maharashtra; the problems that persist in the horticultural sector; recommendations of the state government for the promotion of production and marketing of horticultural produce. It is concluded that export trading requires commodity wise attention both in respect of preharvest and postharvest operations. Development of strategies for production, postharvest handing and export promotion of the horticultural sector is needed to meet the domestic and international demand.
Post Harvest Handling

In India, improper handling leads to spoilage loss (25-30%) of pomegranate fruits and thus, reduces the profit margin of growers. Generally, fruits are picked manually and assembled at grading platform for on-farm grading and packing. However, in developed countries like USA, pickers harvest pomegranate fruits with clippers and place the fruits in picking bags for transfer to harvest bins that will be transported to the packing house. Then the fruits are sorted to eliminate those with severe defects like scuffing, cuts, bruises, splitting and decay. And the remaining fruits are separated according to the magnitude of the physical defect. The fruits with moderate defects are used for processing into juice and those with slight or no defects are marketed fresh. The latter fruits are washed, air dried to remove surface moisture, fungicide treated, waxed, divided into several size grades and packed in shipping containers (fig. 4).

The fruits after harvesting are graded according to their size, weight and colour and are packed in bamboo or wooden boxes or paper carton, using cushioning materials. The pomegranate fruits have better keeping quality than other tropical fruits such as mango, grape and banana. The fruits can be stored for more than 2 months at 4-5°C, if treated with fungicide. It may be possible to store the fruits even for longer period.

As the pomegranate fruits are susceptible to moisture loss, the fruits harvested from the trees are subjected to the following steps viz.,

Quick transport of harvested fruits to the packhouse with available transport facility

- Grading according to the size, shape and colour of fruits
- Packaging in suitable packaging material
- Storing in suitable atmospheric condition

As the pomegranate fruits are susceptible to moisture loss, they need to be stored at high humidity. After harvest, the fruits are graded according to size, wrapped in paper and packed in bamboo baskets or corrugated fibre board (CFB)
Post Harvest Management of Pomegranate

Boxes. In bulk storage, fruits are packed in layers, in wooden crates each containing about 16-18 kg of fruits. Dry grass, rice straws, or paper are used as cushioning material. The pomegranate fruits grown in the state of Maharashtra are graded into 4 grades viz., Super, King, Queen and Prince. The fruits are then packed in corrugated fibre board (CFB) boxes. In a single box, 4-5 fruits of Super size, 6 fruits of King size, 9 fruits of Queen size and 12 fruits of prince size are generally packed (Waskar, 1997).

Factors Affecting Quality and Safety of Pomegranate Arils

One of the limiting factors to increased consumption of fresh pomegranate is the effort needed to extract the arils from the fruit. Thus, providing the consumer with value-added, ready-to-eat pomegranate arils may help increase consumption. Gil et al.(1996a, 1996b) and Hess-Pierce and Kader (1997) investigated the effects of preextraction storage duration and post extraction packaging and handling conditions on deterioration rate of pomegranate arils (juice sacs surrounding the seeds). Pomegranate arils have relatively low rates of respiration (1.5-3 and 3-6 ml carbon dioxide per kilogram per hour at 5°C and 7°C, respectively) and ethylene production (5-15 and 15-30 nl ethylene per kilogram per hour at 5°C and 7°C, respectively). It is possible to produce arils that retain good sensory and microbial quality for up to 14 days of shelf life at 5°C from pomegranate fruits that are stored at 7°C for up to 3 months in air or up to 5 months in controlled atmosphere of 5% O₂ + 15% CO₂ + 80% nitrogen. Mechanical damage to the arils must be minimized during the extraction from the fruit, washing, drying to remove surface moisture and packaging, since packaged arils are more susceptible to decay – causing fungi. CO₂ enriched atmosphere, have a fungi static effect and their optimal range for decay control without inducing off-flavors in the arils is 15 to 20% CO₂ added to either air or 5% O₂. Although intact pomegranate fruits are chilling sensitive, the arils are chilling tolerant and should be kept at temperatures between 0°C and 5°C to maintain their quality and microbial safety. Pomegranate arils that are not damaged are microbially contaminated can be kept at 0°C for up to 21 days, at 2°C for up to 18 days, or at 5°C for up to 14 days in marketable condition (Hess-Pierce and Kader, 2004).
1. Harvest the fruits in crates
2. Transport to grading yard
3. Grading
4. Packaging the graded fruits in CFB boxes
5. Packaged fruits
6. Cushioning material for packaging (paper shreds)

Fig. 4: Post harvest handling of pomegranate
Postharvest Physiology

Ben-Arie (1984) reported that the respiration pattern of the mature fruit was of the 'non-climacteric type' with only traces of ethylene evolved. A 'pseudo-climacteric pattern' of respiration was found in very young immature fruit. The respiration rate of dehisced arils was parallel to that of the intact fruit, but there was no response to exogenous ethylene treatment. Pomegranate fruits have a relatively low respiration rate that declines with time during storage after harvest (Elyatem and Kader, 1984). The ranges of respirations (carbon dioxide production) rates for California-grown “Wonderful” pomegranates were 2-4, 4-8, and 8-10 ml/kg hr at 5°C, 10°C, and 20°C, respectively, while ethylene production rates remained below 0.2 microliter per kilogram per hour. Based on the pattern of carbon dioxide and ethylene production, pomegranate is classified as a nonclimacteric fruit (one that exhibits no dramatic changes in postharvest physiology or composition (Kader and Elyatem, 1984). Both respiration and ethylene production rates increased with temperature. The Q_{10} values for respiration were 3.4 between 0°C and 10°C, 3.0 between 10°C and 20°C, and 2.3 between 20°C and 30°C (Kader et al., 1984). Storage at 5°C or lower resulted in chilling injury; the severity increased with time and with lowered temperature. Chilling injury symptoms, which became more locular septa separating the arils. Pomegranate can be stored at 5°C for up to 2 months, but longer storage should be at 7°C to avoid chilling injury.

Pomegranates are very susceptible to water loss resulting in shriveling of the rind. The higher the temperature and the lower the relative humidity, the greater the water loss. Ideally, pomegranates should be kept at 90 to 95% relative humidity. Use of plastic liners and waxing can reduce water loss, especially under conditions of lower relative humidity (Artes et al., 2000; Nanda et al., 2001).

Exposure of pomegranates to 1, 10, or 100 ppm ethylene in air for up to 13 days at 20°C stimulated their respiration rate in proportion to the ethylene concentration (Kader et al., 1984). Subjecting pomegranates to 100 ppm ethylene in air for 2 days temporarily increased their respiration and ethylene production rates, which then declined to near the levels of control fruits after 3 days in air. This
response occurred again when the fruit were exposed to a second 2-day ethylene treatment after 7 days in storage (Kader et al., 1984). These responses are typical of non-climacteric fruits.

None of the ethylene treatments had a significant effect on skin color, juice color, soluble solids, pH, or titratable acidity of the pomegranate. These results indicate that pomegranates do not ripen once removed from the tree and should be picked when fully ripe to ensure the best eating quality for the consumer. Also, there is no value in treating harvested pomegranates with ethylene (Kader et al., 1984).

**Responses to Modified Atmospheres**

The efficacy of atmospheric modification in controlling decay and maintaining quality of “Wonderful” pomegranate was evaluated. The fruits were kept at 5°C, 7.5°C, or 10°C during one season using air, 2% oxygen, air + 10% carbon dioxide, and 2% oxygen + 10% carbon dioxide. During another season, the following atmospheres were tested: at 5°C and 7.5°C: air, 5% oxygen, air + 10% carbon dioxide, 5% oxygen + 10% carbon dioxide, air + 15% carbon dioxide, 5% oxygen + 15% carbon dioxide. It is found that it is possible to store pomegranates at 7.5°C in 5% oxygen + 15% carbon dioxide for up to 5 months, provided that the level of latent fungal infections at the time of harvest is low and that the pomegranates are sorted carefully after harvest to store only fruits that are free from defects and decay. Carbon dioxide-enriched atmospheres resulted in a lower synthesis rate of anthocyanins and other phenolic compounds and higher concentrations of acetaldehyde, ethanol, and ethyl acetate especially after 4 and 5 months of storage (Hess-Pierce and Kader, 2003).

Accumulation of these volatiles was greater at 7.5°C than at 5°C, but in both cases the highest concentrations were below the threshold values for detection of off-flavor (Hess-Pierce and Kader, 2003). Modified atmosphere packaging with appropriate polymeric films can be used to create a beneficial atmosphere (of 5-10% oxygen plus 10-15% carbon dioxide) during transport and storage of pomegranates (Artes et al., 2000).
Grading

- Grading is important for export and local market to obtain reasonable price.
- Cracked, split, diseased and borer infested fruits should be separated out.
- Precooling of the fruits at farm level is done preferably in cool chamber or in the shade.
- The fruits are graded on the basis of their weight, size, and external (rind) colour.
- The pomegranate fruits grown in the state of Maharashtra are graded into 4 grades viz., Super, King, Queen and Prince (fig. 5).

<table>
<thead>
<tr>
<th>S. No</th>
<th>Grade</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Super</td>
<td>Attractive red colour fruits, &gt; 750g/fruit, free from spot in the rind</td>
</tr>
<tr>
<td>2</td>
<td>King</td>
<td>Attractive red colour fruits, 500-750g/fruit</td>
</tr>
<tr>
<td>3</td>
<td>Queen</td>
<td>Bright red colour fruits, 400-500g/fruit, free from spot</td>
</tr>
<tr>
<td>4</td>
<td>Prince</td>
<td>Red colour fruits, fully ripe fruits, 300-400g/fruit</td>
</tr>
</tbody>
</table>

- Besides, 12A & 12 B grades are also there. Those fruits weighing around 250-300g are graded as 12A (fruits free from spots) & 12 B (with spots).
- The fruits of 12A grade are generally preferred in southern and northern India.
- After grading, the fruits are sometimes treated with ethyl oleate to provide luster.
1 Super size

2. King size

3. Queen size

4. Prince size

Fig. 5 : Fruit grades in pomegranate
Post Harvest Management of Pomegranate

Packing

- The size of packages of pomegranate changes according to their grade (fig. 6).
- Corrugated fibre board (CFB) boxes are used for packaging since they are light in weight, cause less or no damage to fruits, are easy to handle.
- CFB cartons of a standard size (40x20x24cm) are used for packaging.
- 4 fruits of Super size or 6 fruits of King size are packed in each CFB box of size 13"x9"x4” lbh
- 9 fruits of Queen size are packed/ CFB box (15”x11”x4” lbh)
- 12 fruits of Prince size are packed / CFB box (14”x10”x4” lbh)
- The white colour boxes having 5 plies are generally used for export purpose, whereas red coloured ones having 3 plies are used for domestic markets.
- The red colour boxes are cheaper than white colour ones.
- The fruits are wrapped in tissue paper and arranged in 2 rows for export market.
- The cut pieces of waste paper are generally used as cushioning material.
- The graded fruits are placed on cushioning material followed by an attractive red colour paper on the boxes.
- Boxes made of light wood, bamboo basket are also used for packaging.
- Dry grass, rice straws, or paper are used as cushioning material at the bottom and top of box or basket
- Upto 6 dozen fruits are packed in each basket for transport by trucks.

Shrink Film Wrapping

- Fruits having large surface to volume ratio are particularly more susceptible to water loss.
- Individual shrink wrap packaging extends shelflife by preventing moisture loss, maintaining the firmness and reducing the respiration rate (10-20%)
- Protection against abrasion, maintains attractive appearance, avoids condensation of water droplets within the package, prevents secondary infection
Heat shrinkable polymeric film of 20μ thickness used for packaging is low in thickness with high tensile strength, low in permeability to oxygen and water, high in permeability to CO₂, glossy and transparent, ability to shrink at low temperature.

The fruits are loosely sealed initially through a loose sealer (impulse sealer).

Placed on a conveyor belt by providing a base support so that the fruit does not come in direct contact with conveyor belt.

Pass through heat shrunk tunnel, expose to hot blown air for 15-30 seconds (shrink wrap machine or hot gun).

Film is shrunk tightly around the produce.

In case of tray wrap packaging, fruits are first packed in a consumer package and then passed through hot tunnel to form a tight grip.

Shrink wrapped fruits are immediately cooled to remove the excess heat for 2-3 hrs at 5-10°C or by rapid ventilation.

Packed in plastic crate for further storage/transportation.

The shrink wrapped fruits can be stored up to 25 days compared to 10 days without wrapping under ambient temperature.

The shrink wrapped fruits can be stored up to 12 weeks compared to 6 weeks without wrapping under cold storage.
1 Graded fruits as per size

2 Paper shreds as cushion

3 Packaged fruits

Fig. 6: Packaging of pomegranate
Storage

Pomegranate fruits are susceptible to moisture loss and need to be stored at high humidity. After harvest, the fruits are graded according to size, wrapped in paper and packed in bamboo baskets or corrugated boxes. In bulk storage, fruits are packed in layers in wooden crates, each containing 16-18 kg of fruits. Dry grass, rice straw or paper are used as cushioning material (Anon., 1989).

In Maharashtra, the fruits are sorted into four grades viz., Supr, King, Queen and Prince. The fruits are then packed in corrugated fibre board cboxes. Four or five super sized fruits, six King size, nine queen size or twelve prince size fruits will generally fill a box (Waskar, 1995). Innovative packaging developed at IARI using ventilated CFB boxes with CFB partitions having vent holes and layer separators could be very useful for packaging pomegranates (Roy et al., 1992).

The pomegranate fruits have better keeping qualities than other tropical fruits viz., mangoes, grapes and bananas. The storage life of pomegranates is comparable to that of apples (Mukherjee, 1958). Storage at 5°C or lower resulted in chilling injury to the fruits. The peel of Wonderful pomegranate fruit undergoes browning during storage below 14°C (Segal, 1981).

The respiration rate of Wonderful pomegranates remains low (less than 8 ml CO₂/kg/h) when stored at 0-10°C for three months; it increases with temperature. The Q10 values for respiration are 3.4 between 0 and 10°C, 3.0 between 10° and 20°C and 2.3 between 20° and 30°C. The rate of ethylene production from fruits stored below 10°C is mostly below 0.1µl/kg/h (Elyatem and Kader, 1984). An integrated approach on both production and postharvest management using recent technologies on postharvest handling, viz., individual shrink wrapping, waxing, controlled atmosphere (CAS) storage coupled with judicious temperature management practices needs more attention for wide distribution of this delicious fruit in the global market. (Roy and Waskar, 1997).

Holcroft et al., (1998) placed 'Wonderful' pomegranates in jars ventilated continuously with air or air enriched with 10 or 20kPa CO₂ at 10°C for 6
Post Harvest Management of Pomegranate

weeks. Samples were taken initially and after 1, 2, 4 and 6 weeks and postharvest quality attributes were measured. The arils of the pomegranates stored in air were deeper red than the initial controls and than those stored in CO₂ enriched atmospheres. This increased color was associated with increased anthocyanin concentration. Arils from fruits stored in air enriched with 10kPa CO₂ had a lower anthocyanin concentration than air stored fruit, and atmospheres enriched with 20kPa CO₂ had even lower levels, possibly from suppressed anthocyanin biosynthesis. Anthocyanin concentration correlated well with the activity of phenylalanine ammonia lyase but not with glucosyltransferase activity. Moderate CO₂ atmospheres (10kPa) prolong the storage life and maintain quality of pomegranates, including adequate red color intensity of arils.

- As the pomegranate fruits are highly susceptible to water loss resulting in shriveling of rind, the fruits should be chilled to low temperature within 10 hours after harvesting.
- High relative humidity (RH) helps to prevent skin desiccation and rind becoming dark and hard.
- The ideal condition for storage of pomegranate is 5-7ºC and 90-95% RH for storing up to few months.
- This storage condition should be maintained during transport also.
- Susceptibility to chilling varies with maturity and variety. Fruits subjected to too low temperature develop brown discoloration of skin, become pale in color of arils and brown discoloration of white segments separating the arils.
- Keeping quality: 110 days through dipping in 4% CaCl₂ solution for 3 minutes and storing at 2-4ºC and at 85-90% RH
- In bulk storage, fruits are packed in layers in wooden crates, each containing about 16-18 kg of fruits.
- Dry grass, rice straw or paper are used as cushioning material.
- Innovative packaging developed at IARI using ventilated CFB boxes with CFB partitions having vent holes and layer separators could be very useful for packaging pomegranates.
Post Harvest Management of Pomegranate

- Can be stored for some months in a cool dry place, and upto six months under cold storage.
- Low temperature and high humidity helps to store the fruits.
- Fruits stored at 4.5°C & 80-85% RH is free from shrinkage for few months.
- Storage at 10°C is satisfactory if a post harvest fungicide is used.
- Packing material containing sulphur compounds offer 50% more protection from pathogens.

Pomegranate can be best stored at low temperature and high humidity. Fruits stored at 4-5°C and 80-85% relative humidity did not undergo any shrinkage or spoilage in a few months (Mukherjee, 1958). Pantastico et al. (1975) recommended relative humidity of 85-90% for storing Kandhari pomegranates. Storage at lower temperature results in chilling injury, characterized by discolouration and pitting of the rind, internal browning of the pith, paleness of the flesh and increased susceptibility to decay. Storage at 10°C is satisfactory, if a postharvest fungicide is used (Elyatem and Kader, 1984). Kanwar and Thakur (1972) treated packing straw with 5% ammonium bicarbonate, ammonium chloride, diphenylamine, sodium thiosulfate and potassium meta-bisulfite or sulphur for packing pomegranate. The treatment of packing material with sulphur compounds was found to give 50% more fruit protection.

Waskar and Khedkar (1999) reported that the shelf life of pomegranate cv. Ganesh could be extended upto 48 days in zero energy cool chamber when pretreated with waxing coupled with carbendazim (0.1%) as against 30 days at room temperature. Waskar and Gaikwad (2003) reported that different postharvest treatments and storage conditions had a great influence in retaining the physico-chemical constituents and reducing the wastage of pomegranate fruits. They reported that the shelf life of pomegranate fruit could be extended upto 30 days at room temperature (22.17-24.36°C and 52-82% RH), 48 days in cool chamber (16.14-18.22°C and 85-95% RH) and 75 days in cool storage (8°C and 90-95%RH) when treated with waxol (12%) + carbendazim (0.1%). The wax treatment coupled with fungicidal dip is considered beneficial in extending the shelf life of pomegranate in cool chamber and cool storage.
Post Harvest Management of Pomegranates

Pomegranate fruits are susceptible to moisture loss and need to be stored at high humidity. After harvest, the fruits are graded according to size, wrapped in paper and packed in bamboo baskets or corrugated boxes. In bulk storage, fruits are packed in layers in wooden crates, each containing about 16-18 kg of fruits. Dry grass, rice straw or paper are used as cushioning material (Anon., 1989). In the state of Maharashtra (India), pomegranates are sorted into four grades, viz., super, king queen and prince. The fruits are then packed in corrugated fibre board boxes. Four or five super size fruits, six king size, nine queen size or twelve prince size fruits will generally fill a box (Waskar, 1995). Innovative packaging developed at the Indian Agricultural Research Institute using ventilated CFB boxes with CFB partitions having vent holes and layer separators, could be very useful for packaging pomegranates (Roy et al., 1992).

Pomegranate fruits have better keeping qualities than other tropical fruits such as mangoes, grapes and bananas. The storage life of pomegranates is comparable to that of apples (Mukherjee, 1959). Pantastico et al., (1975) recommended an RH of 85-90% for storing Kandhar pomegranates. Storage at lower temperature results in chilling injury, characterized by discoloration and pitting of the rind, internal browning of the pith, paleness of the flesh and increased susceptibility to decay. Storage at 10°C is satisfactory if a postharvest fungicide is used (Elyatem and Kader, 1984). Packing material containing sulphur compounds was found to give fruits 50% more protection from pathogens (Kanwar and Thakur, 1972).

The control of RH is critical in the storage of pomegranate fruits. At low humidity, the skin desiccates readily and the rind becomes dark and hard; the fruits become less attractive and have poor marketability (Lutz and Hardenburg, 1968). Storage at 5°C or lower resulted in chilling injury to the fruits. The severity of the symptoms increases with the exposure time and at temperatures below 5°C (Elyatem and Kader, 1984). The peel of Wonderful pomegranate fruit undergoes browning during storage below 14°C (Segal, 1981).

The storage life of 'Banluang' pomegranate could be extended up to 12 weeks by keeping in sealed polyethylene bags at 10°C, with slight changes in
quality such as weight loss, TSS, titrable acidity (Pota et al., 1987). Individual shrink-wrapping of fruits (cv. Ganesh) and storing at 0°C gave 70 days of shelf life without affecting the quality (Shantha, 1993). Fruits (cvs. 'Gyulosha Rozovaya', 'Uluchshennyl Kazake' and 'Bala Myursal') dipped in 4% CaCl₂ solution for 3 min and stored at 2-4°C and 85-90% RH for 110 days showed low storage loss and retained quality (Treglazova and Fetaliev, 1989). Fruits dried at 30°C and 33% RH, or 20°C and 47% RH, remained acceptable for 3 months or more during storage, depending on the cultivar. Drying affects the quality, but partially dried pomegranate may be useful for processed products (Al-Khatani, 1992).

**Optimal Storage Conditions**

Several postharvest conditions have been evaluated for long-term storage of pomegranates, including low temperature, delayed harvest, intermittent warming (Artes et al., 1998; Artes et al., 2000) controlled atmosphere (Artes et al., 2000; Hess-Pierce et al, 2003; Kupper et al.,1995) and partial drying. Among these procedures, the most successful in reducing decay and physiological disorders is the use of CA storage, which, with a combination of 5% O₂ and 15% CO₂, has been shown to extend pomegranate postharvest life for up to 5 months at 7°C. This combination also avoids the accumulation of high levels of ethanol, observed under CA conditions with lower levels of oxygen, which limits the marketability of the fruit. Optimal storage temperature ranges from 5°C to 8°C, depending on the variety and production area; 7°C is recommended for “Wonderful” pomegranates. In all cases, 90 to 95% relative humidity should be maintained in the surrounding atmosphere. Storage potential ranges from 3-4 months in air and from 4-6 months in a controlled atmosphere of 5% oxygen + 15% carbon dioxide (balance nitrogen). Pomegranates should not be mixed with grapes, since they can be damaged from exposure to the sulfur dioxide that is used to control gray mold on grapes.
Factors Affecting Quality and Safety of Pomegranate Arils

One of the limiting factors to increased consumption of fresh pomegranate is the effort needed to extract the arils from the fruit. Thus, providing the consumer with value-added, ready-to-eat pomegranate arils may help increase consumption. (Gil et al. 1996a; Gil et al., 1996b). Hess-Pierce and Kader (1997) investigated the effects of preextraction storage duration and postextraction packaging and handling conditions on deterioration rate of pomegranate arils (juice sacs surrounding the seeds). Pomegranate arils have relatively low rates of respiration (1.5-3 and 3-6 ml carbon dioxide per kilogram per hour at 5°C and 7°C, respectively) and ethylene production (5-15 and 15-30 ml ethylene per kilogram per hour at 5°C and 7°C, respectively). It is possible to produce arils that retain good sensory and microbial quality for up to 14 days of shelf life at 5°C from pomegranate fruits that are stored at 7°C for up to 3 months in air or up to 5 months in controlled atmosphere of 5% O₂ + 15% CO₂ + 85% nitrogen. Mechanical damage to the arils must be minimized during the extraction from the fruit, washing, drying to remove surface moisture and packaging, since packaged arils are more susceptible to decay causing fungi. CO₂ enriched atmosphere, have a fungi static effect and their optimal range for decay control without inducing off-flavors in the arils is 15 to 20% CO₂ added to either air or 5% O₂. Although intact pomegranate fruits are chilling sensitive, the arils are chilling tolerant and should be kept at temperatures between 0°C and 5°C to maintain their quality and microbial safety. Pomegranate arils that are not damaged are microbial contaminated can be kept at 0°C for up to 21 days, at 2°C for up to 18 days, or at 5°C for up to 14 days in marketable condition (Hess-Pierce and Kader, 2004).
Transportation and Marketing

Transportation

- Fruits are transported safely without any jerks through readily available means of transport and without loss of much time so as to maintain the glossyness and freshness of the fruits during the transit from field to pack house.
-Unload the fruits in the pack house without stacking too many crates over each other so that bruising of fruits is avoided.
- Tractor trolleys / mini vans and carts are used for transport from orchard to local markets after grading and packaging.
- Trucks / rail wagons are the means of transport from local assembly markets.
- The losses are very high (15-20%) during transit through unvented rail wagons
- Wooden boxes are also used for packaging and transportation.

Marketing

Pomegranate is marketed through a cooperative marketing society, locally called as 'Sangha' is a system in which a group of fruit growers join together on cooperative basis to carry on some or all functions involved in transferring fruits from the farmers to the consumption agents of the upcountry markets. Every taluk level, atleast 2 such registered cooperative societies are there. The growers finalise the picking and packing activity only after getting green signals from the Sangha. After receiving the boxes from the growers, the sangha decides at its discretion where, to which commission agent and what number of boxes from assembled produce should be sent. Scheduling the dispatch of consignments in respective lots is the responsibility of the Sangha. Transport cost is in the range of Rs. 4-10 per box.

Through own arrangement: A second method of sale is that the growers send their produce to the distant markets through their own arrangements. This is done in two ways. One way is individual arrangement. Well established farmers having their own means of transport send the produce to the upcountry markets on
their own. The second way is group arrangement, in which about 5 to 10 growers of the particular region, with mutual understanding, come together and make common arrangement for sale of their produce.

Contract sale: The third method is a contract system in which growers sell the standing crop to the trader / middleman on the farm yard itself. This system locally known as khoti. (Pujari, 1998).

**Preparation for Market**

Pickers harvest pomegranates with clippers and place the fruits in picking bags for transfer to harvest bins that will be transported to the packinghouse. Then the pomegranates are sorted to eliminate those with severe defects (such as scuffing, cuts, bruises, splitting, and decay) and the remaining fruits are separated according to the magnitude of the physical defects. Pomegranates with moderate defects are used for processing into juice and those with slight or no defects are marketed fresh. The latter fruits are washed, air dried to remove surface moisture, fungicide treated, waxed, divided into several size categories, and packed in shipping containers. Various ways to immobilize the fruits within the shipping containers may be used to reduce incidence and severity of scuffing and impact bruising during handling. Perforated plastic box liners may be used to reduce water loss during postharvest handling of pomegranates. Packed fruits are cooled by forced-air cooling to 7°C and kept at that temperature and 90 to 95% relative humidity during storage and transport to retail distribution centers.
Post Harvest Management of Pomegranate

Post Harvest Diseases

Nallathambi et al., (2009) reported that pomegranate is infected by different postharvest diseases. According to Palou et al., (2007), gray mould caused by Botrytis cinerea is the most economically important postharvest disease of pomegranate in California (Tedford et al., 2005). Other fungi causing fruit rot include: Aspergillus niger, Penicillium spp., Alternaria spp. etc., (Wilson and Ogawa, 1979; Snowdon, 1990).

In general, the post harvest diseases of pomegranate are due to Grey mould rot, heart rot and penicillium rot. However, considerable damage may be caused by the rotting of fruits due to infection with various fungi in storage and markets (fig.7).

- Aspergillus rot
- Internal rot
- Spicaria rot
- Botrydiplodia rot
- Black mould
- Soft rot
- Penicillium rot

A. nidulans, A. clavatus, B. theobormae and Spicaria spp. are proved to be essentially parasitic in nature whereas R. arrhizus, R. stolonifer, P. expansum and A. niger initiates infection on both injured and uninjured fruits. Application of 2,4 D at the rate of 500ppm as pre infection dip and spraying sulphur compounds on packing straw is useful for control of soft rot during storage.

Grey mould rot

- Grey mould rot is caused by Botrytis cinerea,
- In general, decay begins at the calyx
- The skin becomes light brown, tough and leathery in the advanced stage.
- The arils disintegrate into a dark mass in advanced infections.
- When moist conditions are there, sometimes a characteristic grey mycelium appears on the affected surface (Ryall and Pentzer, 1974).
Heart rot

- This is caused by *Aspergillus* spp. and *Alternaria* spp.
- The disease develops while the fruit is borne in the tree.
- The rind color becomes slightly abnormal in case of affected fruits
- A black line of decay extending from the calyx to the interior part of the fruit may appear in the fruit.
- A mass of blackened arils is present inside the fruit
- The affected pomegranate fruits should be detected and removed by sorters in the pack house.

The rot due to *Alternaria solani* caused damage to the pomegranate fruits during storage and transit (Vyas and Panwar, 1976).

Penicillium rot

- Penicillium rot, caused by *P. expansum* and other *Penicillium* spp.,
- It produces watery areas at the infection site followed by masses of blue or green spores.
- Infections occur at rip breaks due to cracking, mechanical injuries or insect punctures/boreholes.
- Sometimes, other fungi may infect the same injured area and eventually overgrow the penicillium.

Other organisms causing decay in pomegranate fruit includes species of Botrytis, Cladosporium, Phoma, Phomopsis, Rhizopus and Sphaceloma punicae (*Sonawane et al., 1986*). Dipping treatments with aqueous Topsis-M 90.1%) and Bavistin (0.05-0.1%) inhibited the growth of Aspergillus niger (*Padule and Keskar, 1988*).

Infection by *P. reticulosum* causes the inner parts to develop grayish green spore masses without any visible external symptoms the possible toxicity of metabolic products of this fungus was investigated using Paramecium caudatum and white mice; the fungal metabolites caused the death of *P. caudatum* within 3-20 minutes and of mice within 3-7 days after oral administration. *P. reticulosum* has not been known previously as a producer of mycotoxins. Further attention should be paid to its occurrence and possible hazards of its contamination of fruit, particularly that for juice production (*Osipyan and Batikyan, 1983*).
Fig. 7: Fungal rot during postharvest storage
Physiological Disorders

Usually diseases are caused by some living organisms, like bacteria, fungi, virus, protozoa, nematodes, algae etc. Sometimes abiotic factors (non-living agents) like water, temperature, fertilizers etc. also lead to abnormal growth of plant and plant parts, and then it is called disorder.

Fruit cracking

Fruit cracking is a serious problem in pomegranate which occurs more frequently in dry atmosphere of the arid regions. The cracked fruits through sweeter lose keeping quality and are unfit for shipment and are liable to rot. The cracking of pomegranate is believed to occur due to sudden change in soil moisture content (Symconides, 1930; Cheema et al., 1954.) At the time of fruit ripening, if the soil becomes too dry and then irrigated heavily, cracking may result (Hayes, 1953). An increase in air temperature may cause the fruit cracking (fig.8).

It has also assumed that fruit cracking is related to the deficiencies of calcium and boron. This malady is also reported as a varietal character in pomegranate (Palmenoe, 1972) and it was least in cvs. Karakai, Guleshah and Bedana.

Godara (1982) reported that out of 41 strains, P.S. 75-K-3 was tolerant to fruit cracking. The extent of cracking in different cultivars, however, varies. Rind thickness and texture of fruits in various cultivars seem to influence the intensity of cracking (Pareek, 1981). Waskar et al. (2003) reported that no incidence of cracking was observed in Bhagwa variety of pomegranate. Adequate and regular irrigation and interculture throughout the bearing period may reduce the cracking.

- Apart from fruit cracking due to bacterial blight, cracking may also be due to improper soil moisture status and Boron deficiency.
- Calcium and potash deficiency also lead to cracking.
- Cracking due to these reasons is known as 'abiotic fruit cracking'.
- When there is rainfall after a long dry spell or irrigation water is given, the fruits tend to crack.
**Remedy**

- Regulation of soil moisture level through periodical irrigation during fruit development
- Spray of Boron@0.2% (2g/litre)
- Application of calcium and potassium as per the soil test / requirement.

**Internal breakdown /blackening of arils**

Disintegration of arils in mature pomegranate fruit is known as blackening of arils / internal breakdown. It is a serious malady. This disorder can not be identified externally, where the arils become soft, light creamy-brown to dark blackish-brown and unfit for consumption (Ryall and Pentzer, 1974). It is evident in most of the varieties, but the variety Ganesh was found to be the most susceptible, and it seem to have passed this character in hybrids having blood of Ganesh as a parent.

The incidence of internal breakdown is detectable 90 days after anthesis. Its intensity increases as the fruits advances in maturity, more so after 140 days onwards. The incidence is more in ambia bahar. Bigger sized fruits are found to have more incidence. No insect or organism is detected with this malady. The exact causes are not known and remedial measures are difficult to advocate. Therefore, pomegranate fruits should be harvested as soon as they mature.

When the physiological disorder 'internal breakdown' occurs in the pomegranate, the pulp-bearing seeds (arils) do not develop the typical red colour and are somewhat flattened rather than plump. Flavour of the arils is abnormal and many have a streaked appearance due to fine white lines radiating from the seeds. There are no external symptoms. It originated during growth n some seasons, usually only in limited areas.

The incidence develops 150 days after anthesis in variety G-137 and its intensity increases if the fruits are left on the tree upto 165 days (Khodade, 1987). The incidence of browning increases with increase in weight of fruit from 150-200 g (26.60%) to more than 350g (60%).
Prabhu Desai (1989) reported that TSS, acidity, ascorbic acid, total sugars, reducing sugars, calcium, phosphorus and the enzyme catalase were low whereas nonreducing sugars, starch, tannins, nitrogen, potassium, magnesium, boron, polyphenoloxidase and peroxidase enzymes were high in affected arils of cvs. Ganesh and P-23 than in healthy ones.

- When cut open, the apparently healthy looking fruits reveals discolored and shriveled arils.
- It is a serious problem in some cultivars.
- It is more common during 'Ambe bahar'
- The arils become soft, light creamy-brown to dark blackish-brown and unfit for consumption.
- The problem occurs mostly 90 days after fruitset and is much pronounced when left on the tree beyond 140 days after fruitset.
- The possible association of fungi as the cause for this malady or secondary infection is to be confirmed.

Remedy
- Harvesting at appropriate maturity and avoiding the delayed harvest.

Sunscald
- Fruit skin turns scorched due to direct sun rays falling on them.
- The skin turns brown or bronze in colour.
- Fruits facing sunlight are affected. High temperature along with excessive light, crought, and low relative humidity is usually responsible for the sunscald.
- The damage is more pronounced in open canopies

Remedy
- Avoid resorting to heavy pruning and allow optimum canopy development
- Wrap the fruits with paperbags when it is homestead / small scale.
- Spray Kaolin (inert clay) thrice at 15 days interval during hot summer months.
• First spray @5%; second spray @ 2.5% at 15 days after 1st spray; third spray @ 2.5% at 15 days after 2nd spray. The spray interval could be narrowed down when there is heavy rain or wind.

Scald/Superficial browning disorder

A superficial browning disorder (scald) develops on the husk of Wonderful pomegranate fruit during storage. The severity of this disorder can be diminished by delaying the harvest time and by reducing storage temperature, but these measures were insufficiently effective for storage periods exceeding six weeks and at temperatures of 6°C or lower chilling injury also occurred. Scald incidence was correlated with the amount of o-dihydroxyphenols extractable from the husk and was significantly controlled by measures that inhibited their oxidation by polyphenoloxidase. Such postharvest measures included dipping the fruit in boiling water for 2 min and in antioxidant solutions or in bisdithiocarbamate containing 'Maneb' for 30 seconds, or by storing the fruits in a low-oxygen atmosphere. The most effective control of husk scald was obtained by storing late harvested fruits in 2% O₂ at 2°C, but this treatment resulted in accumulation of ethanol, which caused off-flavours. When the fruits were transferred to air at 20°C both ethanol and off-flavours dissipated (Ben-Arie and or, 1986).

Husk scald

• Storage of pomegranate fruits for more than 3 months at 7°C or lower temperature causes husk scald.
• Brown discoloration of the husk in the stem end of the fruit upto 60% of the surface area of fruit.
• The arils and surrounding tissues appear normal and are not affected.
Chilling injury

- Exposure to temperature below 5 °C (-3 °C to 4 °C) for more than 1 month or 5 °C for more than 2 months causes chilling injury in pomegranate.
- Brown discoloration of the skin and increased susceptibility to decay.
- Paleness of the arils and brown discoloration of the white segments separating the arils.

Fig. 8: Fruit cracking in pomegranate
Fruit Coating

*Fresh Coat* series of fruit coating formulations have been developed at the Indian Institute of Natural Gums and Resins (formerly Indian Lac Research Institute), Ranchi, to address the problem of extensive post-harvest losses in the horticultural sector. Coating or 'waxing' is a specialized area of modified atmosphere packaging (MAP), for short-term enhancement of shelf-life of both climacteric and non-climacteric fruits. Waxing optimizes gaseous and water vapor exchange through the lenticels of the fruits and the atmosphere, and essentially delays ripening and shriveling, thereby enhancing its' shelf life. It is a short-term intervention, which is cost effective and convenient. *Fresh Coat* has exhibited remarkable performance in extending shelf life of a wide range of fruits and vegetables, including capsicum, tomato, pointed gourd, apple, peach, and *kinnow*. Presently, its efficacy is being evaluated on spices such as ginger, nutmeg, black pepper, coriander and cumin.

While coating or 'waxing' is common in the US and EU countries, its application is limited in India; few commercial formulations available indigenously are of unspecified composition and safety. In contrast, *Fresh Coat* is based on lac resin, which has FDA clearance for use as a food additive. Other than lac, it contains permitted drying and spreading agents. *Fresh Coat* is completely odorless and flavorless, aqueous-based and dries rapidly after application on suitable substrates. *Fresh Coat* has no gelling problem during storage. Fresh Coat has been optimized with 20% solid content, for thick skinned fruits / vegetables; it can be diluted with water, to 10% solid content (B series) for application on thin-skinned produce like tomato. The formulations can be applied by (1) simple dipping (2) spray (3) brush and (4) through mechanized waxing plants. Trials on mechanized waxing at Central Institute of Post Harvest Engineering & Technology (ICAR), Ludhiana, have indicated that one liter of *Fresh Coat* is sufficient for coating one ton of *kinnow* fruits. The entire mechanized coating is a 3 – 5 minute operation for a single fruit.
In addition to enhancement of shelf life, *Fresh Coat* also has the following features:

1. Improves cosmetic appearance, especially gloss
2. Increases mechanical strength of produce
3. Prevents pathogenic attacks
4. Contains no anti-fungal agents such as *carbendazim* or germicidals such as SOPP.
5. At the consumer's level, the coated peel can be removed, (e.g. citrus varieties). For vegetables, such as brinjal, pointed gourd, capsicum etc., the vegetables can be washed thoroughly to remove the water-soluble coating, before consumption.
6. Is based on toxicologically safe ingredients

Lac is the only natural resin of animal origin, which enjoys considerable commercial importance even today. Together with its associated constituents viz., lac wax and lac dye, this unique commodity is being utilized in various ways by the food processing and packaging industry. Paradoxically, it continues to remain relatively confined – primarily due to lack of awareness, lack of sustained publicity campaigns and also critical information gaps (Sarkar and Kumar, 2003). Lac resin is a polyester type of material, comprising basically of long chain and sesquiterpenic fatty acids (Passey et al., 1998; Sarkar and Agarwal, 1995). With a molecular weight ranging from 660 to 1000, it cannot be termed as a polymer and hence, the term 'oligomer' is better suited for the resin. The resin is unique in the sense that even with its low molecular weight, it has the property of forming films on a wide variety of surfaces. (Sarkar and Kumar, 2003).

Preharvest spray of lac formulation (fig. 9) obtained from Indian Institute of Natural Resins and Gums, Ranchi was found to be very useful in extending the shelf life of pomegranate by 4.5 days over the control (Anon., 2012). Similarly, the postharvest dip of pomegranate fruits in lac formulation (fig. 10) proved to be very useful in extending the shelf life of pomegranate besides retention of glossiness and reduced physiological loss in weight (PLW). It was concluded that ethephon applications delayed ripening and that the observed fruit drop was a direct effect of ethephon rather than of ripening (Shabany and Sharifi 1973).
Edible coating can be described as a food solution that is applied directly on the food surface by various methods such as dipping, spray and brushing method. Also it can be prepared separately as a thin layer and then applied to the outside of a food as a barrier. A variety of different films and coatings viz., starch, seaweed extracts, chitosan material, cellulose derivativies, protein based such as gluten, gelatin, zein, whey and lipid based waxes, resins. It prevents moisture losses while selectively allowing the controlled exchange of gases and ethylene involved in respiration processes. Edible films can provide either clear or milky (opaque) coatings, but consumers generally prefer invisible, clear coating. Combination of hydrocolloids and lipids has been successfully employed as a means to improve the barrier characteristics of edible coatings covering fresh fruit. Such strategy takes advantage of the good water barrier properties of lipids and the good gas barrier properties of hydrocolloids. (Mahawar et al., 2012).

Waxing of fruits alone or in combination with fungicides has been reported to extend the shelf life of pomegranates (Waskar et al., 1999).
1 Control fruit

2 Preharvest spray of lac

3 Lac sprayed fruit with enhanced glossiness

Fig. 9: Preharvest spray of lac formulation in pomegranate
Post Harvest Management of Pomegranate

1 Lac formulation of IINRG, Ranchi

2 Preparation of lac formulation

3 Dipping the fruits in lac

4 Untreated fruits (Control)

5 Air-drying of lac dipped fruits

6 Control vs lac dipped fruits at 8 days after storage

Fig. 10: Post harvest dip of pomegranate fruits in lac formulation
Bottled juice, squash, syrup etc are the products made from pomegranate (Tajuddin and Prakash, 1996). Pomegranate is a high-value crop, mostly used as fresh fruit. It has a long shelf life and is an ideal fruit for long distance transportation and prolonged storage. Apart from its demand for fresh fruits and juice, wine and candy are also gaining importance in world trade (Jadhav and Sharma, 2007).

India is today, one of the largest producers and consumers of food in the world with 16% of the world population and 12 per cent of world food production. On an average Indians spend approximately 35% of their total income on food which is USD 300 billion per year and is likely to grow to approximately USD900 billion by 2020. India has a premium position as the world's second largest producer of fruits and vegetables. It is the largest producer of mango with respect to area and production. India has the world record for highest productivity of grapes. Over 70% of the coconut production comes from this region only. India also enjoys 40% of the cashewnut production and is the largest exporter in the world. Horticultural sector in India comprises of 8.5% of arable land and it provides a dynamic tool for enhancing economic returns for attaining nutritional security, creating implement avenues and ensuring ecological sustainability. This sector also covers a broad spectrum of activities like production, valorization through appropriate post harvest management and processing. Only 6% of the food in India is properly processed which is much lower than the 40% in China and 80% in Malaysia (Pal, 2011). In order to make horticulture a viable enterprise, value addition is essential. Processing is a fast growing sector in the world economy. Presently, less than 2% of the fruits and vegetables are processed in the country as compared to 30% in Thailand, 70% in Brazil, 78% in Philippines and 80% in Malaysia. India already enjoys an enviable position in the world horticulture. Harvest indices, grading, packaging, storage techniques have been developed / standardized for major horticultural crops. The demand for some of the fruits and
Post Harvest Management of Pomegranate

vegetables has grown enormously in country. Value addition through dehydration of fruits and vegetables including freeze drying, dried and processed fruits, vegetables and spices and fermented products play an important role in horticultural crops.

In order to reduce dependence on refrigerated storage, low cost eco-friendly cool chamber for on-farm storage of fruits and vegetables has been developed. For preventing the post harvest losses, proper storage, cold preservation, packaging and transport methods with Hazard Analysis Critical Control Point (HACCP) norms have to be given more thrust. As food consumption patterns are changing towards more conventional foods, the demand for products like pre-packed salads, frozen vegetables etc are increasing.

**Processing for value added products**

The most important demand advantages of processed food in India are due to: Shift in demographic profile: A largely untapped domestic market of 1 Billion consumers with 65% of population below 35 years of age. Growing middle class- From the current size of 50 million to 583 million people by 2025; Higher disposable income: Increase in per capita income and purchasing power; Increased consumer awareness towards quality and hygiene aspects of the food (Pal, 2011). The major demand drivers in the food processing sector are

- Increasing spending on processed food products
- Increasing nuclear families and working women
- Demand for functional foods/ nutraceuticals
- Growth of organized retail and privte label penetration
- Changing demographics – Rise in disposable income
- Increasing Urbanisation – lifestyle and aspirations

Post harvest losses of fruits and vegetables range between 5.8-18% whereas it is 3.9-6.1% in case of cereals, Oilseeds and pulses (Pal, 2011). Fruits and vegetables are wasted annually in India due to several reasons. Unavailability of adequate cold chain facility and lack of awareness of appropriate post harvest and
supply chain management led this huge post harvest losses. Many a times, the farmers are forced to sale their produce immediately after harvest at throwaway price. These sometimes result in glut situation during the harvest and scarcity during the off season. Hence, appropriate postharvest management and valorization of agri-horticultural produce play a crucial role in the growth of food processing sector in India.

Pomegranate fruits being rich source of minerals, vitamins and nutrients finds wide application in traditions Asian medicines both in Ayurvedic and Unani systems. Charak, the Great medical physician of ancient India has prescribed a large number of formulations using almost every part of this plant in the treatment of dysentery, diarrhea, stomachache, inflammations, tapeworm, hynenole-tidosis, dyspepsia, bronchitis and cardiac disorders (Wealth of India Raw materials, 1969). These therapeutic properties are reported to be due to presence of betulic and uroslic acids and different alkaloids, viz., pseudopelletierine, pelletierine and some other basic compounds (Singh et al., 1990). A number of processed products can be manufactured by processing the fruits, which can be preserved for future use.

The fruit is mainly used as an ingredient in cooling and refrigerant mixtures and in the preparation of juice, concentrates, condiment (powders and tablets) and pastes (Saxena et al., 1984). Drying affects the quality, but partially dried pomegranate may be useful for processed products (Al-Khatani, 1992).
Aril Extraction & Minimal Processing

Aril Extraction

- Pomegranate offers some difficulty for the ready consumption of arils as the rind (skin) of the fruit has to be removed to obtain the arils.
- Arils are the juicy sacs encasing the soft seeds.
- Aril extraction machine (aril extractor) and aril extraction tool were designed by Central Institute of Post Harvest Engineering and Technology (ICAR), Ludhiana. (Fig.11).

Minimal processing

Minimal processing is a state of the art technique during which fruits in precut form are subjected physiochemical conditioning without resorting to harsh thermal processing methods.

The technology with regard to fruit and vegetables is defined as 'light processing' (fig. 12). More et al (1994) described a machine consists of a hopper, shaft with knives, concave, outlet chutes for seed and rind and a power transmission system. The seed separation efficiency of the machine was 86% and the average purity of the seed was 96%. Rind separation from the seed was very efficient.

Advantages

- Convenience due to removal of inedible portion
- Reduction in transportation & packing cost
- Elimination of kitchen drudgery due to ready to use or ready to ear nature of products
- Marketing of fresh produce suitable for different end users.

The effect of different types of semi-permeable films and antioxidant solutions on the quality of minimally processed pomegranate arils was evaluated during storage at 4 ± 0.5°C for 14 days. Colour changes were not observed and the browning was slight in all the treatments studied but, highest on those without antioxidants. The pH and acidity values remained constant and the soluble solids content increased only in the arils packaged in perforated polyethylene films due to
the high dehydration. The CO₂ concentration inside the BB4 films reached 22%. The aerobics mesophiles count and moulds and yeasts count were low in all the treatments and in the semi-permeable films a reduction was observed. The uses of semipermeable films in minimally processed pomegranate arils allowed storage for 14 days, at 4 ± 0.5°C, with good chemical, physical and microbiological quality.

It is possible to conclude that the use of semi permeable packages (BE and BB4) with or without application of antioxidant solution, allow storage of pomegranate arils var. Wonderful for 14 days at 4 ± 0.5°C with good physical and microbiological conditions for their commercialization (Sepulveda et al., 2000).

**Flowsheet for the minimum processing of pomegranate arils**

1. **Fruit**
2. **Washing**
3. **Manual threshing**
4. **Selection**
5. **Washing**
6. **Centrifugation**
7. **Drain the water**
8. **Dip in antioxidant solution**
9. **Centrifugation**
10. **Packaging**
11. **Refrigerated storage**
Fig. 11: Aril extractor and aril extraction from pomegranate
Minimally processed aril
cv. Arakta

Minimally processed aril
cv. G-137

Minimally processed aril
cv. Mridula

Fig. 12 : Minimal processing of pomegranate fruit
Anardana

One of the major problems in pomegranate fruits is cracking at maturity leading to huge economic losses to farmers. The traditional utilization of these fruits lies in drying the seeds of these cracked fruits to yield a value added byproduct known as anardana used as acidulent and condiment in Indian curries and also used in ayurvedic and Unani medicines (Wealth of India Raw materials, 1969). The use of cross flow drier has been recommended to get uniform, hygienic and good quality product anardana. The dried product anardana contains more acid (5.8-15.4%), total sugars (9.3-17.5%) and crude fiber as compared to fresh fruit (Singh et al., 1990).

Pomegranate arils, particularly of sour types, can be dried and sold as anardana (fig. 13). This is used as an acidulant in place of tamarind or dried green mango in north India in Indian style curries, chutney and other culinary preparations. The conventional hot air drier takes about 4 h to dry the seed to a moisture level of 16-18%, compared to 15h in solar drier and open sun drying.

**Al-Kahatani (1992)** reported that drying temperature should not exceed 30°C to minimize the deleterious effect on quality. Partially dried pomegranates can have slightly inferior eating quality than those refrigerated, but they might find some applications in the manufacture of jams, jellies, and other products.

**Pruthi and Saxena (1984)** described the procedure for preparation anardana from pomegranate.

Chandel et al. (1989) reported that the arils of wild pomegranate (*Punica granatum*) were dried in a solar cabinet drier. It was found that solar drying of aril with initial moisture content of 72% to a desirable moisture content of 5.2% is achieved in a much shorter period than by open sun drying which takes about 6 days.

According to Kher (1999), wild pomegranate (*Punica protopunica* L.) fruits are a potential source of anardana (dried aril). This species is well adapted to adverse soil conditions and could be grown on waste lands. The wild pomegranate had high acidity of 6.41% compared to 1.02% in Kandhari.
1. Anardana from pomegranate arils

2. Anardana for intake

**Fig. 13 : Anardana**
Pomegranate Juice

Pomegranate juice is a delicious refreshing drink with nutritive and medicinal values (fig. 14). The juice of wild pomegranates yields citric acid and sodium citrate for pharmaceutical purposes. Pomegranate juice is used in the preparations for treating dyspepsia and is considered beneficial in leprosy. Fruit rind contains as much as 26% tannin, which is usually obtained as by-product in the anardana industry. Leaves, seeds and bark have displayed hypertensive, antispasmodic and antihelmintic activity in bioassay. In the last few years, there has been an increasing interest in the search for new pomegranate derived food products. Some of the products that have been developed are minimally processed seeds (ready to eat), jams, juices, jellies, juice concentrates, frozen seeds, seeds in syrup etc. Research showed that pomegranate juice can help to prevent the development of plaque in the arteries and reduce the risk of blood clots. (Anon, 2004).

Pomegranate juice makes a delicious drink. On whole fruit basis, the juice yield is about 42% while from grains, the yield is about 70% (Phandis, 1974). The juice can be extracted by using a spiral type screw press without crushing the seeds. The juice is clarified by heating in a flash pasteurizer at 79-82 °C, cooling, settling for 24 hours racking up and filtering or decanting. The clear juice can be preserved by heat treatment or by using chemicals (600ppm sodium benzoate). The use of sulphur dioxide is banned for pomegranate due to loss of colour by bleaching action of SO₂. After the heating at 80°C, it is filled into bottles while still hot. The bottles are crown corked and pasteurized at 80°C for 30 minutes (Saxena et al., 1984).

The pomegranate juice is highly nutritious and is recommended for patients suffering from gastric troubles. It contains 16.2%TSS and 0.35% acidity; total sugars 12.93%; reducing sugars 12.65% and non reducing sugars 0.28% and ascorbic acid 9.23 mg/100g (Dhumal, 1984). According to Kriventsov and Arendt (1985) the anthocyanin content of most intensively coloured juice of Wonderful was found to be 600–765 mg/100g while the pale juice of their cultivars contained about 200 mg/100g of anthocyanins.
Gabbasova and Abdurazakova (1969) reported that chemical composition of pomegranate juice included the following ranges for fresh juice, titrable acidity (as citric acid), 0.52-1.6%, sugars 15.2-20.5%, pectin 0.5-1.2%, ascorbic acid 3.3-6.4 mg/100ml and vitamin B 0.03-0.08 mg/100 ml of juice.

Lozzi (1969) used the pomegranate juice in the manufacture of carbonated and other soft drinks in the USSR. The soft drinks are also prepared from pomegranate juice (Benk, 1970). The pomegranate juice flavour was used for preparation of confectionary products. Ney (1973) prepared a syrup from pomegranate fruit juice by adding 20ml of red pomegranate extracts to 11 ml of sugar syrup. Phandis (1974) reported that the pomegranate fruits could be successfully used for preparation of juice based beverages and for dessert purpose.

Subrashanyan (1983) described an equipment for separating seeds from pomegranate skin, the seeds are then pressed for juice extraction, the juice being used in the manufacture of beverages as natural pomegranate juice or a food additive.

Waskar and Deshmukh (1994) reported the juice extraction method using crushed pomegranate arils and heating at 40°C gave maximum juice recovery (60.21%) with an adequate quantity of anthocyanins, sugars and comparatively lower tannins and it recorded the highest score during organoleptic evaluation. The juice may be extracted from whole fruits or derinded fruits.. On a whole fruit basis, the yield of juice is about 50 % while from grains the yield is about 76-85%. A prototype machine which can separate arils and skin from fruits without causing damage to arils has been developed by MPKV, Rahuri (More, 1998). The pomegranate juice cv. Ganesh was packed in colourless and amber colour glass bottles and stored at room temperature (29.5-21.4°C) and low temperature (5°C). It was found that after the storage period of 180 days, there was maximum retention of anthocyanins (30-70mg/100ml) in pomegranate juice packed in amber colour glass bottles and stored at low temperature (Waskar and Deshmukh, 1995). Waskar (2000) reported that the blending of pomegranate and kokum juice in 80% +20% gave good TSS, Acidity and anthocyanins. This combination rated the highest organoleptic score. It was also observed that with the addition of kokum juice in an
pomegranate juice, the TSS of resultant blend was found to be decreased with increase in acidity. However, there was a substantial increase in anthocyanin content of blended juice.

The Kandhari variety of pomegranate, which contains richly coloured purple grains, gives a highly delicious juice. The fruit is cut into quarters and the grains separated and pressed in a basket press. The juice can also be extracted from the cut quarters as such by applying gentle pressure in a basket press. The juice is filtered through thick cloth. It is then bottled and preserved by pasteurization or by addition of sodium benzoate. The flavour is rather delicate and becomes less intense gradually during prolonged storage. The juice can also be converted into an attractively coloured pleasant tasting squash of 55 to 60 degrees Brix (Siddappa & Bhatia, 1954). The well known syrup of grenadine is prepared from pomegranates. (Lal et al.,1998).

The soluble polyphenolic content of pomegranate juice (0.2-1.0%) includes anthocyanins, catechins, tannins and gallic and ellagic acids (Aviram et al., 2000). The preparation and processing of pomegranate juice as given by Srivastava and Kumar (2002) is mentioned below.

**Flowsheet for processing of pomegranate juice:**

```
Post Harvest Management of Pomegranate

<table>
<thead>
<tr>
<th>Pomegranate fruits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washing</td>
</tr>
<tr>
<td>Cutting into 4 equal pieces</td>
</tr>
<tr>
<td>Separation of arils</td>
</tr>
<tr>
<td>Pressing of arils (basket press)</td>
</tr>
</tbody>
</table>
```
Post Harvest Management of Pomegranate

1. Straining
2. Bottling
3. Crown corking
4. Pasteurization
5. Cooling
6. Storage

1 Pomegranate juice a refreshing drink
2 Packaged pomegranate juice

Fig. 14: Pomegranate juice
Wine Making

Oenology

- Oenology refers to the science of wine making.
- In ancient Indian literature, wine has been referred as 'somarasa' - the drink of gods.
- Generally, table wines contain 9-12 per cent alcohol and in fortified wines, the maximum alcohol is around 20 per cent.
- Pomegranate juice is rich in vitamins, minerals and antioxidants. Wine from pomegranate juice could be an alternative to grape wine as it has nutritional & medicinal properties.

Wine & health benefits

- A drink that results from complete or partial alcoholic fermentation of pomegranate juice due to the action of yeasts belonging to Saccharomyces species is known as wine and its use in several Ayurvedic medicines is well cited.
- Wine represents a safe, non-toxic healthful beverage and provides calories, vitamins and minerals. Dry wine can be a source of non-sugar calories as well as dietary variety for diabetics and other restricted diets. It is useful for the persons with arteriosclerosis and hypersensitive vascular conditions.
- It is a common cultural and religious beverage in many countries. Moderate consumption tends to give greater longevity and better health.
- Wine is of great value as food adjunct and flavour enhancer. It complements meals and forms a regular part of diet providing valuable nutrients. It can serve as a tonic.
- Moderate consumption has medicinal utility. It induces sleep, increases appetite, stimulates gastric secretions and produces mild diuresis. Use of vermouth in formal medical therapy is well established.
Advantages of wine making

- Avoids postharvest losses and fetch remunerative prices to the orchardists
- Reduce wastage of fruits, provide healthful drinks in the internal market
- As tool for earning foreign exchange by exporting wines
- Industrialization of the fruit belt
- Economic upliftment of the people
- To generate employment opportunities

Fermentation

The term fermentation is derived from the Latin verb *fervere*, to boil, thus describing the appearance of the action of yeast on fruit or malted grain. The boiling appearance is due to production of CO₂ bubbles caused by anaerobic catabolic reaction of sugars present in the extract. Fermentation is the anaerobic conversion of sugar to carbon dioxide and alcohol by yeast or any group of chemical reactions induced by living or nonliving ferments that split complex organic compounds into relatively simple substances. In fermentation, a chemical change is brought on by the action of microscopic yeast, molds and bacteria. The souring of milk, the rising of dough and the conversion of sugar to alcohol are all examples of fermentation. Ethanolic fermentation was one of the first chemical reactions observed by humans. In nature, various types of food deteriorate as a result of bacterial action. Early in history, humans discovered that this kind of change could result in the formation of products that were enjoyable to consume. The spoilage (fermentation) of fruit juices, for example, resulted in the formation of primitive forms of wine.

Alcohol is produced when yeast enzymes break up sugar into roughly equal parts of alcohol and carbon dioxide gas. Everyone may be familiar with bakers yeast but most yeast occur wild in nature and grow on plants and animals where they are dispersed through the air and water. Yeast spores are everywhere and if they get a chance they will gladly ferment your grape juice or malt. The problem with this is that there are thousands of strains of wild yeast and most of them are not
suitable for fermenting alcohol. Most wild yeast will give your beer or wine strange off-tastes and a lot of them are not very tolerant to alcohol which means you will end up with a partly fermented, low alcoholic, sweet beverage. Hence, brewers and wine makers use yeast that is specifically cultured for the fermentation alcoholic beverages. Wine is the product made by the normal alcoholic fermentation of the juice of sound, rope grapes, and the usual cellar treatment.

**Classification of wines**

The Classification of wines as given by Singh & Purohit (2011) is as follows.

- Table wines, also called still or natural wines, are consumed primarily as complements to food.
- Sparkling wines, for example, champagne, distinguishable by their effervescence, are drunk for the most part on festive occasions.
- Fortified wines, such as sherry or vermouth, are most commonly drunk before or after meals and are also frequently used in cooking. These wines are termed fortified because of their alcoholic and sugar content are increased and their fermentation arrested by the controlled addition of a more potent liquor, usually a grape brandy, during the wine making process; this results in an alcoholic content of 15 to 22 per cent by volume, as against 9 to 14 per cent for most table wines.

**Table wine**

Table wines are further classified by color, as red, white, or rose (pink); and by character, as sweet or dry Singh & Purohit (2011).

Red wines are made from dark grapes, the skins of which are allowed to remain in contact with the fermenting juice for a period of 2 days to three weeks, depending on the character and depth of colour desired. White wines may be made from white (that is green) grapes or from dark grapes, but in the latter case the grape skins and pressed juice do not come into contact. True rose wines are from dark grapes; their skins remain in contact with the juice only until they have turned it a pale pink.
In the wine lexicon, sweet and dry (as opposed to sour, which denotes wine gone bad) are antonyms, sweet wines being characterized by a relatively dulcet flavour and dry wines by an absence of sweetness.

1. Dry wine is wine in which the fermentation of the sugars is practically complete. Most dry wines contain a small amount of sugar even though the quantity may be so slight as to escape detection by the sense of taste.

2. Sweet wine: is wine in which the alcoholic fermentation has been arrested. Such wines contain sufficient sugar for taste perception. Wines may be fortified by the addition of brandy or wine spirits.

3. Fortified dry wine: is dry wine to which brandy has been added out which conforms in all other particulars to the standard of dry wine. Fortified by the addition of brandy or wine spirits.

4. Sparkling wines: is wine in which the after part of the fermentation is completed in the bottle, the sediment being disgorged and its place supplied by wine or sugar liquor and/or dextrose liquor, and which contains, in 100 cc (20°C) not less than 0.12g of grape ash. Such wine contains considerable carbon dioxide.

Other types of wines (Singh & Purohit, 2011):

1. Modified wine, ameliorated wine, corrected wine: is the product made by the alcoholic fermentation, with the usual cellar treatment of a mixture of the juice of sound, ripe grapes with sugar and/or dextrose, or a syrup containing not less than 65% of the sugars, and in quantity not more than enough to raise the alcoholic strength after fermentation to 11% by volume.

2. Raising wine is the product made by the alcoholic fermentation of an infusion of dried or evaporated grapes, or of a mixture of such infusion or raisins with grape juice.

There are about one thousand components have up to now been identified. Wine contains 85-90% water. It also comprises ethyl alcohol resulting from yeast fermentation. All wine incorporate some acidity from organic acids, among which
is tartaric acid characteristic of grape. Acetic and propionic acids are the volatile acids found in sound wines. Acetic acid is the principal volatile acid of young wines but wines contain traces of propionic acid in addition. Formic acid is usually found in diseased wines, together with acetic acid. The mineral composition of wine is special as it contains potassium, calcium, magnesium, sodium, iron, sulfates, phosphoruses, all of which necessary to cover daily needs of human beings. Potassium salts and sulfates are known to facilitate diuresis. Wine contains a small amount of azoted substances as well as 20 aminoted acids among which praline can be found. It is surprising to notice that the concentration of aminated acid in wine is very close to that of human blood. Wine contains vitamins of the group B, and above all vitamin P which reinforces the cell wall of capillary vessels, lessening the risks of hemorrhage and oedema. Wine also comprises more specific components which give it its personality (aroma components) such as phenolic components. The phenolic component is an element whose molecule incorporates several phenolic functions among which are phenolic acids, anthocyanins and tannin.

**Fruit wine**

1. Fruit wine: It is wine (other than grape wine or citrus wine) produced by the normal alcoholic fermentation of the juice of sound, ripe fruit (including resorted or unresorted pure condensed fruit must), with or without the addition, after fermentation, or pure condensed fruit must and with or without added fortifying fruit spirits or alcohol, but without other addition or abstraction except as may occur in cellar treatment.
2. Berry wine: it is fruit wine produced from berrie.
3. light fruit wine: it is fruit wine having an alcoholic content not in excess of 14 per cent by volume
4. Natural fruit wine: It is fruit wine containing no fortifying fruit spirits and added alcohol
5. Fruit wine derived wholly (except for sugar, water, or added alcohol) from one kind of fruit shall be designated by the word wine qualified by the name of such fruit, eg. Peach wine, blackberry wine

Wine from other agricultural products (Singh & Purohit, 2011):

Wine of this class is wine (other than grape wine, citrus wine, or fruit wine) made by the normal alcoholic fermentation of sound fermentable agricultural products, wither fresh or dried, or of the restored or unrestored pure condensed must thereof, with the addition before or during fermentation of a volume of water not greater than the minimum necessary to correct natural moisture deficiencies in such products, with or without the addition, after fermentation, or pure condensed must, and with or without added alcohol or such other fortifying spirits as will not alter the character of the product, but without other addition or abstraction except as may occur in cellar treatment.

1. Light wine of this class is wine having an alcoholic content not in excess of 14 per cent by volume.

2. Natural wine of this class is wine containing no fortifying spirits or added alcohol.

3. Resin wine is wine of this class made from dried grapes.

4. Sake is wine of this class produced from rice in accordance with the commonly accepted method of manufacture of such product.

Wine of this class derived wholly (except for sugar, water or added alcohol) from one kind of agricultural product shall, except in the case of sake, be designated by the word 'wine' qualified by the name of such agricultural product, eg., honey wine, raising wine, dried blackberry wine.

Vermouth is a compound having an alcoholic content of not less than 15 per cent by volume, made by the mixture of extracts from macerated aromatic flavoring materials with grape wine containing fortifying frappe spirits or added alcohol, and manufactured in such a manner that the product possesses the taste, aroma, and characteristics generally attributed to vermouth.
Post Harvest Management of Pomegranate

Pomegranate Wine

Adsule et al. (1995) described that pomegranate wine is the product of anaerobic fermentation by yeast in which the sugars are converted into alcohol and carbon dioxide (fig. 15).

Sevda and Rodrigues (2011) reported that the wine yeast *Saccharomyces cerevisiae* NCIM3095 was immobilized in sodium alginate beads as a biocatalyst in pomegranate wine making. The immobilized biocatalyst was suitable for pomegranate must fermentation at ambient temperatures. In order to optimize immobilization conditions, a study was conducted using various concentrations of alginate, cell loading and bead diameter. The optimized parameters were alginate concentration 3% w(w/v), initial cell loading 8g/100ml and cell bead diameter of 3mm. In comparison to free cells, the rate of fermentation by immobilized cell proved to be greater, showing suitability for fruit wine production.

For preparations of pomegranate wine, the whole fruits are pressed without crushing or juice may be extracted from pomegranate grains, which gives a yield of 76-85% (Adsule & Patil, 1995). Sugar is added to the juice to bring it to 22-23°Brix. Potassium meta-bisulphite is added to the juice to prevent the growth of undesirable microorganisms. The juice is fermented with starter wine yeast and the wine is aged and finished in the same manner as the red grape wine. If a sweet table wine is desired sugar is added to 8-10°Brix. The wine is flash pasteurized at 60°C, bottled hot and sealed. Fortifying the sweetened wine to about 20% alcohol can make wine like port.

Steps in Preparation of pomegranate wine

In general, the composition of pomegranate wine is as follows.

- 11.9% alcohol
- 0.85g/100g total acidity (as citric acid)
- 0.07g/100ml volatile acidity
- 11.50 °Brix.

Sevda and Rodrigues (2011)
The preparation of pomegranate wine involves the following steps:

- Extract the **juice** (less astringent) from the pomegranate fruits
- Add **sugar** to the juice and adjust the TSS to 22-23 °Brix
- Add **potassium metabisulphite** to prevent the growth of undesirable microbes
- **Pasteurize** the juice at 60°C temperature
- **Ferment** the juice by addition of starter wine yeast
- Allow the fermentation process to continue till desired level of **alcohol** is obtained
- **Clarify** the wine by adding bentonite or by centrifugation
- The wine is allowed for **ageing** and finished in the same manner as in red grape wine
- For sweet table wine, sugar is added to bring its **TSS to 8-10°** Brix after aging; the wine is flash pasteurized 60°C, bottled hot and sealed; the bottles are cooled in sprays of cold water.

**Chemical composition and sensory properties of different fruit wines**

The chemical composition and sensory properties of different fruit wines were reported (Kotecha, et al., 2011).

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Fruit</th>
<th>TSS (°Brix)</th>
<th>Total sugar (%)</th>
<th>Acidity (%)</th>
<th>Polyphenol (mg%)</th>
<th>Alcohol (% v/v)</th>
<th>Overall acceptability (out of 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grape</td>
<td>6.70</td>
<td>6.50</td>
<td>0.68</td>
<td>32.0</td>
<td>8.20</td>
<td>15.20</td>
</tr>
<tr>
<td>2</td>
<td>Pomegranate</td>
<td>6.00</td>
<td>4.30</td>
<td>0.64</td>
<td>254.0</td>
<td>7.6</td>
<td>15.65</td>
</tr>
<tr>
<td>3</td>
<td>Banana</td>
<td>8.40</td>
<td>7.17</td>
<td>0.88</td>
<td>47.2</td>
<td>71.1</td>
<td>15.00</td>
</tr>
<tr>
<td>4</td>
<td>Guava</td>
<td>7.60</td>
<td>5.16</td>
<td>0.49</td>
<td>153.0</td>
<td>6.6</td>
<td>13.84</td>
</tr>
<tr>
<td>5</td>
<td>Ber</td>
<td>7.35</td>
<td>5.28</td>
<td>0.38</td>
<td>200.0</td>
<td>7.6</td>
<td>12.47</td>
</tr>
<tr>
<td>6</td>
<td>Sapota</td>
<td>8.00</td>
<td>6.69</td>
<td>0.91</td>
<td>322.0</td>
<td>7.2</td>
<td>14.75</td>
</tr>
<tr>
<td>7</td>
<td>Strawberry</td>
<td>8.01</td>
<td>6.72</td>
<td>0.88</td>
<td>313.0</td>
<td>7.0</td>
<td>14.63</td>
</tr>
<tr>
<td>8</td>
<td>Jamun</td>
<td>5.69</td>
<td>4.42</td>
<td>0.83</td>
<td>112.8</td>
<td>8.4</td>
<td>15.90</td>
</tr>
</tbody>
</table>
## Post Harvest Management of Pomegranate

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Fruit</th>
<th>TSS (°Brix)</th>
<th>Total sugar (%)</th>
<th>Acidity (%)</th>
<th>Polyphenol (mg%)</th>
<th>Alcohol (% v/v)</th>
<th>Overall acceptability (out of 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Pineapple</td>
<td>6.40</td>
<td>2.80</td>
<td>0.75</td>
<td>27.0</td>
<td>9.3</td>
<td>15.70</td>
</tr>
<tr>
<td>10</td>
<td>Orange</td>
<td>6.00</td>
<td>1.04</td>
<td>0.67</td>
<td>43.0</td>
<td>10.2</td>
<td>15.66</td>
</tr>
<tr>
<td>11</td>
<td>Orange + Passion fruit</td>
<td>5.90</td>
<td>0.90</td>
<td>1.92</td>
<td>3.4</td>
<td>9.4</td>
<td>15.33</td>
</tr>
</tbody>
</table>
Post Harvest Management of Pomegranate

1. Fresh juicy fruits
2. Washing with tap water
3. Extract the arils
4. Juice extraction
5. Pomegranate juice
6. Test the TSS of juice
7. Sucrose supplementation
8. Final TSS adjustment to 24°Brix
9. Pouring the juice to vessel
10. Placing in the autoclave
11. Autoclaving
12. Remove the vessel from autoclave
13. Placing the vessel
14. Vessel placed over the stand
15. Starter wine yeast
16 Inoculation with yeast
17 Set the fermentor
18 Run the fermentor for 7-10 days
19 Examining the wine quality

20 Packaged pomegranate wine
21 Pomegranate wine a medicinal drink

Fig. 15: Wine making from pomegranate juice
Pomegranate juice is useful for the patients suffering from Leprosy, high cholesterol level, heart patients and kidney problems. Processed fruit products will not only avoid the seasonal glut in the market but also helps in stabilization of market prices and provide incentive for increase in the area and production of pomegranate fruits. Pomegranate fruits can be processed into different products like juice, squash, syrup, jelly, wine, anardana, anar-rub (Adsule and Patil, 1995).

Pomegranate juice can be utilized for preparation of ready-to-serve (RTS) beverage by adding cane sugar and citric acid and maintaining TSS upto 15° Brix and 0.25% acidity (Vaidya et al., 1998).

More et al. (1999) prepared ready-to-serve beverage from juice using 20 per cent juice and adding cane-sugar, citric acid by marinating 15° Brix and 0.25 per cent acidity.

Khurdiya (1989) studied the carbonation in fruit beverages. For preparation of carbonated beverages, the ingredients required are water, sweeteners, acidulates, colorings, flavorings, carbon dioxide, clouding agents, emulsifiers etc. The fruit based carbonated drinks from lime, phalsa, jamun, ber and apple and described the processing, preservation of their carbonated drinks (Khurdiya, 1990).

Rokade et al. (2001) prepared carbonated beverage from grapes. The carbonated beverage with 0.3 per cent acidity and 14° Brix scored for the maximum organoleptic properties. Jadhav et al. (2002) conducted studies on preparation and storage of carbonated beverage from tamarind juice.

**Organoleptic evaluation of the carbonated beverage**

The organoleptic evaluation of the carbonated beverage was carried out according to the method of Amerine et al. (1965) on 9-point hedonic scale. The average score of the panel of judges for different quality characteristics viz., color, flavor, taste and overall acceptability was reported.
The physico-chemical characteristics of pomegranate juice were reported by several workers viz., Swaminathan (1977), Sood et al., (1982), Jagtap et al. (1992), Waskar and Deshmukh (1995) and Vaidya et al. (1998).

**Physico-chemical properties of pomegranate juice var.Ganesh used for preparation of carbonated beverage.**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Range</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>-</td>
<td>Pale yellow</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>7.9-8.9</td>
<td>8.4</td>
</tr>
<tr>
<td>Width (cm)</td>
<td>7.9-8.3</td>
<td>8.1</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>230-330</td>
<td>280</td>
</tr>
<tr>
<td>TSS (Brix)</td>
<td>14.2-14.6</td>
<td>14.4</td>
</tr>
<tr>
<td>Acidity (%)</td>
<td>0.34-0.40</td>
<td>0.38</td>
</tr>
<tr>
<td>pH</td>
<td>2.9-3.15</td>
<td>3.00</td>
</tr>
<tr>
<td>Reducing sugars (%)</td>
<td>10.40-11.60</td>
<td>11.00</td>
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<tr>
<td>Non-Reducing sugars (%)</td>
<td>2.80-3.03</td>
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<tr>
<td>Total sugars (%)</td>
<td>13.40-14.20</td>
<td>13.88</td>
</tr>
<tr>
<td>Ascorbic acid (mg/100ml)</td>
<td>13.20-14.80</td>
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</tr>
<tr>
<td>Anthocyanin content (mg/100ml)</td>
<td>18.20-20.30</td>
<td>19.25</td>
</tr>
</tbody>
</table>

**Combination of pomegranate and ginger juice for preparation of carbonated beverages**

The various combinations of pomegranate juice and ginger juice used for preparation of carbonated beverages are as follows.
Code for treatment | Pomegranate juice | Ginger juice |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>10%</td>
<td>1%</td>
</tr>
<tr>
<td>G2</td>
<td>10%</td>
<td>2%</td>
</tr>
<tr>
<td>G3</td>
<td>10%</td>
<td>3%</td>
</tr>
<tr>
<td>G4</td>
<td>15%</td>
<td>1%</td>
</tr>
<tr>
<td>G5</td>
<td>15%</td>
<td>2%</td>
</tr>
<tr>
<td>G6</td>
<td>15%</td>
<td>3%</td>
</tr>
<tr>
<td>G7</td>
<td>20%</td>
<td>1%</td>
</tr>
<tr>
<td>G8</td>
<td>20%</td>
<td>2%</td>
</tr>
<tr>
<td>G9</td>
<td>20%</td>
<td>3%</td>
</tr>
</tbody>
</table>

All the above treatments were evaluated for taste, colour, flavour and overall acceptability by a panel of five judges and accordingly the mean values are given below.

**Organoleptic evaluation of carbonated beverage cv. Ganesh**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Taste</th>
<th>Colour</th>
<th>Flavour</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>8.5</td>
<td>7.7</td>
<td>8.2</td>
<td>8.5</td>
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<tr>
<td>G2</td>
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<td>7.5</td>
<td>7.5</td>
<td>8.2</td>
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<td>G4</td>
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<td>G5</td>
<td>8.3</td>
<td>7.8</td>
<td>7.3</td>
<td>8.2</td>
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<td>G6</td>
<td>7.6</td>
<td>7.8</td>
<td>7.1</td>
<td>8.0</td>
</tr>
<tr>
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<tr>
<td>G8</td>
<td>7.5</td>
<td>8.0</td>
<td>7.2</td>
<td>7.6</td>
</tr>
<tr>
<td>G9</td>
<td>7.7</td>
<td>7.7</td>
<td>7.1</td>
<td>7.8</td>
</tr>
<tr>
<td>Mean</td>
<td>7.95</td>
<td>7.78</td>
<td>7.38</td>
<td>8.03</td>
</tr>
<tr>
<td>CD (p=0.05)</td>
<td>0.017</td>
<td>0.017</td>
<td>0.018</td>
<td>0.018</td>
</tr>
</tbody>
</table>
From the organoleptic evaluation, G1 (pomegranate juice 10% and Ginger juice 1%) has maximum score for taste, colour, flavour and overall acceptability in comparison with all treatments. Nakadi et al (2001) reported similar results in case of ready-to serve (RTS) beverage from pomegranate juice. The results obtained are comparable with the values reported by Shelar (2001).

Carbonated beverages of various composition have been reported in several studies. The values of various chemical parameters of carbonated beverage prepared from 10% pomegranate juice and 1% ginger juice are comparable with those reported by Khurdiya et al. (1989), Rokade et al. (2001), Shelar (2001) and Jadhav et al (2002).

**Schematic diagram for preparation of carbonated beverage from pomegranate juice**

```
Pomegranate juice
  ↓
Addition of ginger juice
  ↓
Addition of citric acid
  ↓
Addition of sugar
  ↓
Addition of syrup in the pre-sterilized bottles
       ↓
CO2  pure water
     ↓
Carbonated water
```
Thus, carbonated beverage from pomemgrante juice cv. Ganesh with the combination of 10% and 1% ginger juice had maximum acceptability. The carbonated beverage of excellent quality could be prepared from the combination of pomegrante and ginger juice (Sandhan and Kushare, 2008).
Other Processed Products

The other processed products prepared from pomegranate included jam, jelly etc. (fig. 16).

Concentrate & beverage

Fruit juice concentrates, singly or in blended form, is products with great potential on account of their wide acceptability in fruit based beverages. The beverages prepared from pomegranate are highly refreshing and nutritious. A technology has been identified using Bentolite at 1-1.5g/litre and gelatin at 0.05g/litre as clarifying agents giving better results than milk, charcoal or casein (Gubaniya et al., 1984). The prepared beverage using this technology is excellent in taste and has attractive red colour due to high retention of anthocyanins. The anthocyanins reported in pomegranate are having antioxidant properties.

Pomegranate jam

Jam is a product prepared by boiling the fruit pulp with sufficient sugar to a reasonably thick consistency, firm enough to hold the fruit tissues in position. Jam can be prepared from one kind of fruit or from the mixture of two or more kinds of fruits. Jam contains 0.5-0.6% acid and invert sugar should not be more than 40%.

A product known as anar rub with fairly good keeping quality can be made by concentrating pomegranate juice and heating the mixture on a slow fire for a long period. The finished product has a thick consistency and contains 70-75% TSS (Siddappa & Bhatia, 1954). Anar rub can be stored for one year and it is utilized as a jam, which can be enjoyed with bread etc.

The products were made from frozen Mollar pomegranate juice, adding pectins, saccharose and citric acid. It was observed that during the processing treatment, 25% of the pigments are destroyed. They continue to degrade during preservation, which depends more on temperature than the light. The degradation was highest at 37°C whereas the best preservation is at 5°C.
Syrup and Jelly

A syrup of 60°Brix with an added acidity of 1.5% as citric acid has a bright purplish-red colour and a delightful taste and flavour. It was preserved by pasteurization or by adding sodium benzoate.

A jelly is a semi-solid product prepared by boiling a clear strained solution of pectin containing fruit extract, free from pulp, after the addition of sugar and acid. A perfect jelly should be transparent, wellset, but not too stiff and should have the original flavor of the fruit. It should be attractive in colour and keep its shape when removed from the mould. It should be firm enough to retain a sharp edge but render enough to quiver when pressed. It should not be gummy, sticky or syrupy or have crystallized sugar. The product has to be free from dullness, with little or no syneresis (weeping) and neither tough nor rubbery. As pomegranate is low in pectin and acid content, it can be used but only after addition of pectin powder.

An attractive jelly can be prepared from pomegranate juice (Phandis, 1974). Preparation of jelly on a small-scale from sweet-sour pomegranates from Ganesh variety also has given very good results (Adsule et al., 1992).
1 Pomegranate jam

2 Pomegranate jelly

Fig. 16: Other processed products from pomegranate
Rind Powder

The rind powder is slightly granular in texture with mild flavor of pomegranate. It is used as tooth powder and in medicine and cosmetic industries. The recovery of rind powder is around 13.3% (Sheikh, 2006). This is an excellent source of β-carotene, potassium, phosphorus and calcium. The powder contains 16.5% polyphenols and 5.35% mineral matter. Pomegranate cv. Mridula and wild pomegranate have high potential for producing rind powder which retains its quality for more than six months when stored in low temperature. Mature and healthy pomegranate fruits are washed and then cut manually to separate the arils from the rind. The rind is cut into small pieces (10-20mm) using a sharp knife and is dried in an air circulatory tray dryer at 60°C for 48 hours. Dried pieces are cooled and powdered in a grinder, sieved (60 mesh sieve) and packed in high density polyethylene (HDPE) bags.

Utilization of pomegranate waste

Rind powder, leaves and flowers can be processed / utilized in many useful products. The rind powder is rich in beta-carotene, polyphenol, and minerals. Pomegranate rind powder has potential for use in medicines, leather and drying industry and for making tooth powder. In India, rind is used in diarrhoea and chronic dysentery, often combined with opium. It is used as an injection in leucorrhoea, as a gargle in sore throat in its early stages and in powder in intermittent fever (Kachru et al, 2008).

Gargling with boiled water of rind of pomegranate helps in eliminating foul smell.

Taking one-tablespoon ground dried rind of pomegranate with water twice a day stops excessive bleeding. Applying the paste of dried ground rind of pomegranate mixed with rose water and leaving it for sometime before wash, eliminate spots, freckles in the face & increases the glow of complexion, thus making skin soft busters. Ground fresh leaves of pomegranate gives relief in heart
palpitation. Applying paste of ground fresh leaves of pomegranate over the lower abdomen (in case of feeling pain) helps in controlling abortion or miscarriage. Taking 20-30g of ground fresh leaves of pomegranate with black pepper in one cup of water twice a day controls leucorrhoea (Kachru et al. 2008).

Dry the flowers of pomegranate in shade, grind and strain. Massaging this powder on teeth helps in curing bleeding gums. By taking pomegranate flower (dried in shade) with honey twice a day cures too much urinating tendency. Flowers also yield a red dry & with leaves and seeds were used by ancients as astringent medicines and to remove worms (Kachru et al., 2008)
Appendix -1

Composition of pomegranate during hasth bahar

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameters</th>
<th>Bhagwa</th>
<th>Ganesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Moisture (%)</td>
<td>81.27</td>
<td>81.17</td>
</tr>
<tr>
<td>2</td>
<td>Total Ash (%)</td>
<td>0.53</td>
<td>0.46</td>
</tr>
<tr>
<td>3</td>
<td>Protein (%)</td>
<td>1.41</td>
<td>1.21</td>
</tr>
<tr>
<td>4</td>
<td>Fat (%)</td>
<td>0.31</td>
<td>0.24</td>
</tr>
<tr>
<td>5</td>
<td>Crude fiber (%)</td>
<td>1.6</td>
<td>1.40</td>
</tr>
<tr>
<td>6</td>
<td>Carbohydrates (%)</td>
<td>14.88</td>
<td>15.52</td>
</tr>
<tr>
<td>7</td>
<td>Calorific Value (K cals/100g)</td>
<td>67.95</td>
<td>69.08</td>
</tr>
<tr>
<td>8</td>
<td>Minerals (mg/100g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i</td>
<td>Iron</td>
<td>0.39</td>
<td>0.30</td>
</tr>
<tr>
<td>ii</td>
<td>Zinc</td>
<td>0.26</td>
<td>0.19</td>
</tr>
<tr>
<td>iii</td>
<td>Calcium</td>
<td>2.50</td>
<td>2.71</td>
</tr>
<tr>
<td>iv</td>
<td>Magnesium</td>
<td>10.22</td>
<td>7.78</td>
</tr>
<tr>
<td>v</td>
<td>Copper</td>
<td>0.26</td>
<td>0.28</td>
</tr>
<tr>
<td>vi</td>
<td>Manganese</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>vii</td>
<td>Phosphorus</td>
<td>34.73</td>
<td>28.23</td>
</tr>
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<td>9</td>
<td>Vitamins (mg/100g)</td>
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<td></td>
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<tr>
<td>i</td>
<td>Thiamine</td>
<td>0.09</td>
<td>0.06</td>
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<tr>
<td>ii</td>
<td>Niacin</td>
<td>0.22</td>
<td>0.25</td>
</tr>
<tr>
<td>iii</td>
<td>Ascorbic acid</td>
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<td>22.42</td>
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<td>10</td>
<td>Total Carotenoids (µg/100g)</td>
<td>26</td>
<td>27</td>
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</table>

(Source: NRCP Annual Report 2007-08, NRCP, Solapur)
## Appendix -2

### Composition of pomegranate during ambe bahar

<table>
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<tr>
<th>Sl.No.</th>
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<th>Bhagwa</th>
<th>Ganesh</th>
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<tbody>
<tr>
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<td>Total Ash (%)</td>
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<td>Protein (%)</td>
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<td>Fat (%)</td>
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<td>1.22</td>
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<tr>
<td>5</td>
<td>Crude fiber (%)</td>
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<tr>
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<td>Carbohydrates (%)</td>
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<td>75</td>
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<td>Minerals (mg/100g)</td>
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<td>Maganese</td>
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<td>Phosphorus</td>
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<td>Total Carotenoids (µg/100g)</td>
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(Source: NRCP Annual Report 2008-09, NRCP, Solapur)
## Composition of pomegranate during Mrig bahar

<table>
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<th>Parameters</th>
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<th>Ganesh</th>
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<tbody>
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<td>Total Ash (%)</td>
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<td>i</td>
<td>Iron</td>
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<td>Vitamins (mg/100g)</td>
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<tr>
<td>i</td>
<td>Thiamine</td>
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<td>0.07</td>
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<tr>
<td>ii</td>
<td>Niacin</td>
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<td>iii</td>
<td>Ascorbic acid</td>
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<td>10</td>
<td>Total Carotenoids (µg/100g)</td>
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<td>14.00</td>
</tr>
</tbody>
</table>

(Source: NRCP Annual Report 2008-09, NRCP, Solapur)
## Appendix -4

### Pomegranate varieties suitable for specific purposes

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<th>Varieties</th>
<th>Purpose</th>
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<td>1</td>
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</tr>
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<td>Ganesh</td>
<td>For table purpose, Wine making</td>
</tr>
<tr>
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<td>Ruby</td>
<td>Table purpose, Juice extraction</td>
</tr>
<tr>
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<td>Jalore Seedless</td>
<td>For table purpose</td>
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<td>5</td>
<td>Arakta</td>
<td>For juicing, Table purpose</td>
</tr>
<tr>
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<td>Mridula</td>
<td>For juicing, Table purpose</td>
</tr>
<tr>
<td>7</td>
<td>Amlidana</td>
<td>For dehydration (Anardana making)</td>
</tr>
<tr>
<td>8</td>
<td>Wonderful</td>
<td>Juicing</td>
</tr>
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</table>
## Appendix -5

### Chemical and mineral composition of pomegranate rind powder

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Fruit</th>
<th>Rind Powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>78.00</td>
<td>8.40</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>1.60</td>
<td>0.94</td>
</tr>
<tr>
<td>Total sugar(%)s</td>
<td>14.60</td>
<td>3.20</td>
</tr>
<tr>
<td>Ascorbic acid (mg/100g)</td>
<td>16.00</td>
<td>2.40</td>
</tr>
<tr>
<td>B-carotene (ppm)</td>
<td>-</td>
<td>12.52</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>0.70</td>
<td>5.35</td>
</tr>
<tr>
<td>Polyphones (%)</td>
<td>-</td>
<td>16.50</td>
</tr>
<tr>
<td>Acidity (%)</td>
<td>0.58</td>
<td>4.13</td>
</tr>
<tr>
<td>Calcium (mg/100g)</td>
<td>10.00</td>
<td>35.90</td>
</tr>
<tr>
<td>Phosphorus (mg/100g)</td>
<td>70.00</td>
<td>1100.00</td>
</tr>
<tr>
<td>Magnesium (mg/100g)</td>
<td>44.00</td>
<td>140.00</td>
</tr>
<tr>
<td>Potassium (mg/100g)</td>
<td>133.00</td>
<td>1550.00</td>
</tr>
<tr>
<td>Sodium (mg/100g)</td>
<td>0.90</td>
<td>40.00</td>
</tr>
<tr>
<td>Iron (mg/100g)</td>
<td>0.89</td>
<td>30.00</td>
</tr>
<tr>
<td>Zinc (mg/100g)</td>
<td>0.82</td>
<td>30.00</td>
</tr>
<tr>
<td>Manganese (mg/100g)</td>
<td>0.77</td>
<td>2.00</td>
</tr>
<tr>
<td>Copper (mg/100g)</td>
<td>0.34</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(Source: Production technology of arid & semiarid fruits, MPKV, Rahuri, 1996)
## Appendix -6

### Recommended temperature, relative humidity and storage life of pomegranate

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Temperature (°C)</th>
<th>Relative humidity (%)</th>
<th>Storage life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pomegranate</td>
<td>0-5</td>
<td>90-95</td>
<td>2-3 months</td>
</tr>
<tr>
<td>Custard apple</td>
<td>7-10</td>
<td>85-90</td>
<td>1-2 weeks</td>
</tr>
<tr>
<td>Guava</td>
<td>5-10</td>
<td>90</td>
<td>2-3 weeks</td>
</tr>
<tr>
<td>Jack fruit</td>
<td>11-12.8</td>
<td>85-90</td>
<td>3-5 weeks</td>
</tr>
<tr>
<td>Mango</td>
<td>13</td>
<td>90-95</td>
<td>2-3 weeks</td>
</tr>
<tr>
<td>Pineapple</td>
<td>7-13</td>
<td>85-90</td>
<td>2-4 weeks</td>
</tr>
</tbody>
</table>

(Source: Bose, T.K. et al., 1999)
## List of basic equipments useful in post harvest technology of pomegranate

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aril extractor</td>
<td>machinery for extraction of arils from pomegranate fruit</td>
</tr>
<tr>
<td>Aril extraction tool</td>
<td>tool for extraction of arils from pomegranate fruit</td>
</tr>
<tr>
<td>Precision Electronic balance</td>
<td>To weigh the chemicals / samples precisely</td>
</tr>
<tr>
<td>Digital vernier caliper</td>
<td>To measure diameter for fruit / fruit products</td>
</tr>
<tr>
<td>Digital pH meter</td>
<td>pH of fruit juice / processed products</td>
</tr>
<tr>
<td>Penetrometer (Fruit pressure tester)</td>
<td>firmness/ pressure of fruits in terms of lbs/in² or kg/cm²</td>
</tr>
<tr>
<td>Hand refractometer</td>
<td>Total soluble solids of juice in terms of °Brix</td>
</tr>
<tr>
<td>Fermentor</td>
<td>Fermented products like winemaking</td>
</tr>
<tr>
<td>Viscometer</td>
<td>Viscosity of fruit products</td>
</tr>
<tr>
<td>Texture analyzer</td>
<td>Texture of fruit / fruit product</td>
</tr>
<tr>
<td>Autoclave</td>
<td>Sterilization of containers, glass jars at 121.1°C &amp; 15 lbs pressure</td>
</tr>
<tr>
<td>Dehydrator</td>
<td>For dehydration</td>
</tr>
<tr>
<td>Hot water bath</td>
<td>for digestion of samples</td>
</tr>
<tr>
<td>Filter press</td>
<td>for clarification of extracted juice during enzymatic clarification</td>
</tr>
<tr>
<td>UV vis spectrophotometer</td>
<td>estimation of nutrient components in fruit products</td>
</tr>
<tr>
<td>Bottle washing machine</td>
<td>washing the glass bottles</td>
</tr>
<tr>
<td>Equipment</td>
<td>Purpose</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>Automatic bottle filling machine</td>
<td>for filling the liquid /semisolid product in bottles</td>
</tr>
<tr>
<td>Crown corksing machine</td>
<td>for corksing the bottles and sealing them air tight</td>
</tr>
<tr>
<td>PP cap sealing machine</td>
<td>For pilferage proof cap sealing of glass bottles with squash</td>
</tr>
</tbody>
</table>
References


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