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REVIEW ARTICLE

Recent Advances and the Developments in the Pomegranate Processing and Utilization: A Review

S. S. Dhumal*, A. R. Karale, S. B. Jadhav and V. P. Kad

Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar (Maharashtra) 413 722, India.

*Corresponding Author:

S. S. Dhumal

Email: sangram1326@hotmail.com

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Abstract

Pomegranate, because of its high nutritive value, therapeutic properties, antioxidant capacity, potentially bioactive compounds and consumer appeal is considered as a 'Superfruit' and a food medicine. In spite of numerous health benefits, pomegranate consumption is still not wide spread, due to the difficulties of extracting the arils from the fruit and the irritation of phenolic metabolites which stain the hands during preparation of seeds which is time consuming. Excellent flavour, nutritive value and medicinal properties of pomegranate fruit indicates its good potentiality for processing into value added products having extended shelf life. The new post-harvest technology application with reference to product diversification played an important role in the context of increased pomegranate production by keeping the original nutritional quality of the fruit. The pomegranate juice is considered as the one of the nature's most powerful antioxidants. The research on the development of the new pomegranate derived products such as minimally processed pomegranate seeds, jams, marmalades, single strength juices, jellies, juice concentrates, frozen seeds, refrigerated seeds, seeds in syrup, candied arils, arils in brandy and in vinegar, carbonated beverages, pomegranate wine, pomegranate syrup etc. has been carried out. The processed products such as anardana, juice, concentrate; syrup and jelly were highly acceptable because of their nutritive and dessert qualities and palatability. The modified atmosphere packaging offered an additional innovative tool for the optimal use and value addition of lower grade pomegranate fruits. The minimally processed pomegranate arils and frozen arils packed in punnets and pomegranate juice are the most appealing products to consumers than whole fruit. Pomegranate juice can be used in beverages, for jellies, for preparation of pomegranate juice concentrate, as flavouring and colouring agents and for dietetic and prophylactic treatment purposes. This new sector of pomegranate industrial processing will allow the use of non commercial pomegranate fruits with some physical defects and fruit disorders, having the good quality juice and seeds, to the preparation of these new products, thus improving pomegranate utilization for human health.

Keywords: Pomegranate, Processing, Utilization, MAP, Value addition.

1. Introduction

The pomegranate has been grown since ancient times for its delicious fruits and as an ornamental garden plant for its red, orange or occasionally, creamy yellow flowers. The pomegranate (*Punica granatum* L.) belongs to the punicaceae family. It is also known as the *Chinese apple or Apple of Carthage or Apple with many seeds*. Pomegranate is known as a super fruit of next generation and is a native of Iran to Himalayan region and is extensively grown in Iran, Spain, India and USA as well as in most Near and Far East countries (Schubert *et al.*, 1999).

In India, pomegranate is considered as a crop of the arid and semi arid regions because it withstands different soil and climate stresses. It thrives best under hot dry summer and cold winter provided irrigation facilities are available (Saxena *et al.*, 1987). Owing to its low maintenance cost, tolerant to biotic and abiotic stresses, high yielding potential, better keeping quality and higher nutraceutical fruit value, popularity of pomegranate is increasing among the growers and consumers worldwide. It is found growing wild in the hills of Himalayas covering the entire hilly tract of Jammu and Kashmir, Himachal Pradesh and parts of Uttar Pradesh. The main pomegranate growing states in India are Maharashtra, Karnataka, Gujarat, Rajasthan, Uttar Pradesh, Andhra Pradesh and Tamil Nadu. India ranks first in the pomegranate production (8.07 lakh tonnes) in the world, on an area of 1.09 lakh hectares with productivity of 7.40 t/ha (Anonymous, 2010). Maharashtra, a pomegranate basket of India, covers 0.82 lakh ha area (75%) with the production of 5.50 lakh tones (68 % of the total pomegranate production in the country). More than 90 percent of the fresh produce is utilized for domestic fresh consumption and export. Spain (45%) and Iran (15%) competes the India in International market.

Excellent flavour, nutritive value and medicinal properties of pomegranate fruit indicates its good potentiality for processing into value added products having extended shelf life. In order to exploit and popularize the medicinal and nutritive values of the pomegranate to its fullest extent, it becomes essential to explore the different ways of minimal processing and post harvest technology applications. In India, in spite of the known nutraceutical benefits and great global demand for potentially pomegranate derived products; the pomegranate processing industry is not developed due to lack of technological developments for commercialization, resource personnel and scientific research database. Thus the post harvest losses are very high (20-40%). About 10-15% fresh produce lose their market value and consumer acceptability due to improper post harvest management. Minimizing these losses can increase their supply without bringing additional land under cultivation. A number of processed products can be manufactured and preserved for future time satisfying the consumer perception of a high nutritional quality and convenience produce. These could also help to have the good returns and make the availability of the fruit throughout the year increasing the shelf life of the pomegranate fruits as such for a considerable period.

The purpose of this review paper is to present the recent advancements, current status and developments in the pomegranate processing and their utilization. It also focuses on the increasing interest in the search for new pomegranate derived food products, the application of the new post harvest technologies and identifies future prospects for the development and utilization of pomegranate processing.

2. Pomegranate Fruit Quality Characteristics

Pomegranate fruits are irregular round in shape with coriaceous rinds that vary from yellow, green or pink to bright deep red, depending on the variety and stage of ripening (Holland *et al.*, 2009). The fruit, a false berry, balausta type, is internally having multi ovule chambers separated by membranous walls (septum) and a fleshy mesocarp. The chambers are filled with shiny red seeds encased in a succulent and edible red pink pulp called arils. The arils develop from the outer epidermal cells of the seed and elongates to a very large extent in a radial direction (Fahan, 1976). The colour of arils varies from white to deep red depending upon the variety. Fruit quality depends largely on sugar and acid content of the juice. The edible portion of the portion of pomegranate is an excellent dietary source as it contains a significant proportion of organic acids, soluble solids, polysaccharides, vitamins, fatty acids and mineral elements of nutritional significance (Table 1 and 2) (Ewaida *et al.*, 1987; Fadavi *et al.*, 2006). The physico-chemical properties of pomegranate fruit cultivars have reported by several researchers (Artes *et al.*, 2000a; Opara *et al.*, 2009; Zarei *et al.*, 2010). They showed that the physico-chemical properties of pomegranate cultivars vary among the agro-climatic zones. Several chemical properties such as anthocyanins, vitamin C, total phenolics and total tannins have also been reported by Al-Said *et al.* (2009) and D'Aquino *et al.* (2010).

Table 1: Chemical and Mineral Composition of Pomegranate Fruits

Constituent	Edible fruits	
	Fresh fruit	Dry Weight basis
Moisture (%)	78	19
Protein (%)	1.6	7.27
Total Sugars (%)	14.6	66.36
Ascorbic acid (mg/100g)	16.0	72.73
Ash (%)	0.7	3.18
Acidity (%)	0.58	2.64
Mineral (mg/100g)		
Calcium	10	45
Phosphorous	70	318
Magnesium	44	200
Potassium	133	604
Sodium	0.90	4.09
Iron	1.79	8.14
Zinc	0.82	3.73
Manganese	0.77	3.50
Copper	0.34	1.55

Source: Chavan *et al.* (1995).

3. Therapeutic Properties of Pomegranate

Pomegranate is a very promising and emerging crop for its refreshing arils, juice and its chemo preventive properties having medicinal value (Hertog *et al.,* 1997). The pomegranate has been regarded as a food medicine of great importance for therapeutic purposes like colic, colitis-diarrhea, dysentery, leucorrhea, paralysis and headache (Sadeghi *et al.,* 2009; Schubert *et al.*, 1999).

Table 2: Nutritional composition of the pomegranate

Constituent	Unit	Value per 100 gram of edible portion
Proximates		
Water	g	80.97
Energy	Kcal	68
Protein	g	0.95
Total lipid	g	0.30
Ash	g	0.61
Carbohydrate, by difference	g	17.17
Total dietary fiber	g	0.6
Total sugars	g	16.57
Minerals		
Calcium	mg	3
Iron	mg	0.30
Magnesium	mg	3
Phosphorous	mg	8
Potassium	mg	259
Sodium	mg	3
Zinc	mg	0.12
Copper	mg	0.070
Selenium	mcg	0.6
Vitamins		
Vitamin C (Total ascorbic acid)	mg	6.1
Thiamin	mg	0.030
Riboflavin	mg	0.030
Niacin	mg	0.300
Pantothenic acid	mg	0.596
Vitamin B_6	mg	0.105
Total Folate	mcg	6
Vitamin A	IU	108
Vitamin E	mg	0.60
Vitamin K	mcg	4.6

Source: USDA National Nutrient Database for Standard Reference, Release 17 (2004)

It finds wide application in the traditional Asian medicines both in Ayurvedic and Unani systems. The therapeutic properties are reported to be due to the presence of betulic and urosolic acids and different alkaloids such as pseudo pelletierine, pelletierine and some other basic compounds (Singh *et al.,* 1990). There has been a remarkable increase in the commercial farming of the pomegranates globally, due to the potential health benefits of the fruit such as its high antioxidant, anti-mutagenic, anti-hypertension activities and the ability to reduce liver injury (Du *et al.,* 1975; Tsuda *et al.*, 1994; Lansky *et al.*, 1998; Gil *et al.,* 1996a). Pomegranate anthocyanins have been demonstrated scavenging activities. The pomegranate polyphenolic compounds are able to elevate the antioxidant capacity of the human body. Pomegranate fruit is also known for its anti-inflammatory and anti-atherosclerotic effect activity against osteoarthritis, prostate cancer, heart disease and HIV-I (Malik *et al.*, 2005; Sumner *et al.*, 2005). The juice from the pomegranates is one of the nature's most powerful antioxidants. Gil *et al.* (2000) reported the antioxidant activity of pomegranate and compared to those of red wine and a green tea infusion showing that the commercial pomegranate juices had three times higher antioxidant activity than those of red wine and green tea. Pomegranate juice also increases the body's resistance against infections, acts as cooling beverage and tones up the function of kidney, liver and heart. All the parts of the tree, the roots, the reddish brown bark, leaves, flowers, rinds and seeds have featured in medicine for thousands of years as they are rich source of different chemical constituents (Table 3).

Table 3: Pomegranate plant parts and its constituents

Plant Part	Constituents
Pomegranate Juice	Anthocyanins, glucose, ascorbic acid, ellagic acid, gallic acid, caffiec acid, catechin, Minerals, amino acids, quecertin, rutin
Pomegranate seed oil	95% Punicic acid, ellagic acid, sterols
Pomegranate pericarp (peel, rind)	Phenolic punicalagins, gallic acid, catechin, flavones, flavonones, anthocyanidins
Pomegranate leaves	Tannins, falvone glycosides, luteolin, apigenin
Pomegranate flower	Gallic acid, Urosolic acid, triterpenoids including maslinic and asiatic acid
Pomegranate roots and bark	Ellagitannins, punicalin and punicalagin, piperidine alkaloids

(Source: Jurenka, 2008)

The sweet varieties of pomegranate are considered a good laxative while those which are intermediate between sweet and sour are regarded as valuable in stomach inflammations and heart pain. The pomegranates have recently been found to boost activity of an enzyme which protects the cardiovascular risks.

4. Pomegranate Processing

Ongoing global drive for a healthier diet has led to a rise in demand for convenient and fresh food produce, with high nutritional value and free of additives (James Celeb *et al.,* 2011). Pomegranate indicates the great scope for the processing into value added products having extended shelf life. The fruit disorders such as sun burnt husks, splits and cracks and husk scald on whole fruit reduces marketability and consumer acceptance. The new sector of pomegranate processing allows the use of the fruits with low quality fruits that cannot be commercialized, for the preparation of the new products. Despite of great potential for pomegranate derived products, the industrial processing of pomegranate is scarce due to peeling difficulties and lack of technological development for industrial processing of pomegranate (Lopez-Rubira *et al.,* 2005; Gil *et al.*, 1996).

The activity of research and development on pomegranate has aimed at the application of new refrigerated technologies to extend the commercial shelf life of pomegranate to cash the market for export of fresh pomegranates keeping its original quality and at the search of new pomegranate derived products.

The pomegranate can be processed into products like minimally processed fresh arils, juice, squash, beverage, molasses, juice concentrates, frozen seeds, jam, jelly, marmalades, grenadine, wine, seeds in syrup, pomegranate spirits, pomegranate powder, pomegranate rind powder, anardana, confectionery, pomegranate seed oil etc. (Yadav *et al.,* 2006). Fig 1 shows the possible utilization of the pomegranate fruit in industrial processing.

5. New Technologies for Pomegranate Storage

The pomegranate is classified as a non-climacteric fruit. In spite of the non climacteric nature of the fruit, quantitative and qualitative loss still occur due to postharvest handling processes, resulting in chilling injuries, husk scalding, weight loss and decay of pomegranate (Kader *et al.,* 1984). The new physical treatment applications have been reported to prolong the shelf life of the fresh pomegranates. These treatments modifies the environmental conditions of pomegranate storage, effecting the fruit physiology and biochemistry and inhibiting the development of micro-organisms contaminating the fruit surface, keeping the original physico-chemical quality of the fruit. Kader *et al.* (1984) and Artes, (1992) recommended a fast pre-refrigeration using forced air as one of the simplest ways to extend the commercial life of pomegranate up to 2-3 months by keeping storage temperature around 5^0C. Artes and Tomas-Barberan (2000) reported the applications of controlled and modified atmospheres (CO_2 enriched and / or reduced O_2), use of the thermal treatments for fruit conditioning and curing and intermittent warming during the cold storage to avoid fungal developments and physiological disorders that develops below 5^0C.

Active MAP involves a quick process of gas flushing or gas replacement or the use of gas-scavenging agents to establish a desired gas mixture within the package (Kader and Watkins, 2000). Studies have shown that modified atmosphere packaging (MAP) and controlled atmosphere storage (CAS) have the ability to delay quality loses and thus extends the shelf life of fresh or minimally processed or fresh-cut produce (Gil *et al.*, 1996a-b; Lee *et al.*, 1995; Church, 1994; Holcroft *et al.,* 1998; Sepulveda *et al.,* 2000). Modified atmosphere packaging can result in reduction in the respiratory activity by decreasing O_2 concentration, delay in softening and ripening and a reduced incidence of the various physiological disorders and pathogenic infestations.

MAP sensing and Monitoring: 'Smart' or 'active' or 'intelligent' packaging system is introduced to improve the safety of MAP products and to extend the technology to a broader spectrum of products (Church, 1994). Summers (1992) defined the Smart packaging as an interaction between the packing system and the product itself which confers intelligence appropriate to function and use of the product with the ability to sense or to be sensed and to communicate. Nano biosensors can serve as the best smart packaging tool for MAP sensing and monitoring. Artes *et al.* (1998) recommended a controlled atmosphere of 5% O_2 + 0% to 5% CO_2 composition for the storage of Mollar pomegranate at 5^0C with RH 95 % to minimize decay weight loss and chilling injuries. In contrast, Kader (1995) recommended a gas composition of 3% to 5%O_2+ 5% to 10% CO_2 for storage of pomegranate at 5^0C. Studied also reported the chilling injuries to pomegranates when stored at temperatures lower than 5^0C (Kader, 1986; Artes, 1992).

6. Pomegranate Juice Processing

Pomegranate contains 48 to 52 per cent of edible part on the whole fruit basis, which comprises of 78 percent juice and 22 percent seed. The seeds along with arils are crushed and juice is extracted and marketed as a fresh juice due to its excellent flavour, attractive fragrance, delicious taste and high nutritive and medicinal value. Production of juice from the pomegranate arils proved to be one of the important methods of value addition. The juice can be processed possible into the squash, syrup, nectar, jelly, concentrate and such other products. Pomegranate juice can be used as an ingredient providing colour to the other products. The pomegranate juice is a rich source of polyphenols. The phenolic constituents of pomegranate such as the anthocyanins give the colour and other polyphenols such as flavonoids and some non flavonoids are responsible of antioxidant properties, astringency and bitterness to juice (Gil *et al.,* 2000). The antioxidant qualities of pomegranate juice, makes it appealing for the production of health supplements and nutraceuticals (Singh *et al.,* 2002).

6.1 Extraction of pomegranate juice

Up to date, commercial pomegranate juice production has only been mentioned by Cemeroglu (1977), Vardin (2000) and Saxena *et al*. (1987). The foremost challenge in juice extraction is the peeling of the fruit as it is time consuming and irritating as the hands get stained due to polyphenols and oxidative enzymes. For juice extraction, the fruits are prepared by rolling it on the hard surface to weaken the seed sacks within the fruit. A prototype machine which can separate arils and skin from fruits without causing damage to arils has been developed by MPKV, Rahuri. A hand tool is designed by CIPHET, Ludhiana, India, for easy extraction of arils from fruits. The basic method for extraction of juice involves the cut opening of the fruit, seed separation and pressing in screw press or basket press. In another method, the fruits are quartered and crushed or the whole fruits may be pressed in hydraulic press and juice is strained out. Juice is extracted from the mature pomegranate seeds of sweet type cultivars like Mollar, Bhagwa etc. by pressing and liquefying. The pressing method gave the greater quantity as well as better quality. On whole fruit basis the juice yield is about 42% while on aril weight basis yield is about 70% (Phadnis, 1974). Ozkan (2002) described packaged press method for extraction of pomegranate juice from separated arils and clarified the pomegranate juice with gelatin at 4^{O}C overnight and stored filtered juice at -30^{O}C. While Saxena *et al.* (1987) recovered 36.41 % the juice by cutting the pomegranate fruits into quarters and pressing them in a rack and cloth hydraulic press under moderate pressure. The hydraulic extraction of juice should be at a pressure less than 100 psi to avoid undue yield of tannins from the rind. The phenolic constituents of the pomegranate juice are responsible for the colour, astringency, bitterness as well as the formation of cloudy appearance of fruit juices during concentration and storage as reported by de Simon *et al.* (1992) and Spanos and Wrolstad (1992). Adsule and Patil (1995) reported the average pomegranate juice recovery by hand press method. The yield of juice was about 50 per cent on whole fruit basis, while from grains the yield was about 76 to 85 per cent. Chobe (1999) separated grains and rind by pomegranate seed extractor and recovered 55 per cent pomegranate juice by crushing them in screw type juice extractor. Vardin and Fenercioglu (2009) obtained the 30 to 40 percent pomegranate juice by pressing the whole pomegranate fruit in the manually operated packaged type press in batches of 10 kg for 5 minutes. They also reported that the pomegranates can be pressed as a whole or as a divided or as granulated sac, but the best results were obtained by using whole fruits considering the time and cost but resulted in the juice with excessive astringency and bitterness due to squeezing of phenolic compounds. Neifar *et al.* (2009) extracted pomegranate juice having pH 4.1 and TSS 15^{0}Brix by using the Philips electric juice centrifuge (centrifuge method) and stored the juice at -20^{0}C. Alpher *et al.* (2005) described the process of extraction of pomegranate juice by pressing the two halved cut fruit into laboratory type press which yielded 40-50 percent juice. Marti *et al*. (2001) described a process for extraction of pomegranate juice having 3.8 pH, in which, aril pressurization followed by centrifugation at 6000 rpm for 10 minutes was used. Kumbhar *et al.* (2002) reported that the average pomegranate juice recovery on whole fruit basis by hand press method, mechanical method and screw type juice extractor method was 71.6, 66.0 and 81.0 per cent, respectively. The pomegranate juice can also be extracted by squeezing the arils gently by hand press method (Sandhan, 2003; Singh *et al.,* 2005).

6.2 Clarification of Pomegranate Juice

Clarification or fining is one of the most important steps in fruit juice processing. The procedure helps to remove active haze precursors and thus decrease the potential for haze formation during storage. The rind of the pomegranate fruit contains a very large amount of excessively ‘puckery’ tannin which enters the juice and makes it undrinkable if the whole fruit is crushed or pressed with excessive pressure (Vardin, 2000). Nutritionist, however, recommend in contrast to preserve these compounds during the fruit juice processing because of their health protective effects. Pomegranate juice contains only trace amount of pectin. Therefore it can be filtered easily after pressing without clarification. However clarification is necessary to prevent the formation of cloudy appearance during storage and also to improve the taste of the product. If the clarification is not employed, the product has bitter taste due to high tannin content. These polyphenols contribute to haze formation through the mechanisms involving prior polymerization or condensation leading to the formation of the polymeric complexes and collected at the bottom of the fruit juice bottle when stored. In pomegranate, most of the tannin presents in the outer part of the fruit. During the pressing, it passes to the juice. The main purpose of the clarification is to reduce the amount of the tannin and decrease the astringency of the product. Effective use of clarification agents requires optimization of their method of preparation as well as determination of the appropriate concentration needed to achieve clarification. For clarification, gelatin, bentonite, clays etc. may be used as flocculating agent. Sahin *et al.* (1992) observed the positive charge of gelatine at the pH of fruit juice which removed the negatively charged phenolic compounds, by forming heavy flocculent precipitate forms. But if the gelatin is added above the level, turbidity increases (Cemeroglu *et al.,* 1982). Pectinase enzyme plays important role in clarification of the fruit juices by depectination (Vilquez *et al.,* 1981). The centrifugation method may also be employed for the clarification of the fruit juices. Vardin (2000) reported the conventional heating treatment to raw pomegranate juice to inactivate naturally present enzymes and to destroy the vegetative microorganisms. He further opined that heating or pasteurization of the pomegranate juice can be applied after clarification and filtration as heating before clarification increases the stability of haze formation which hinders the clarification of juice permanently. The natural clarification can be suitably employed for clarification of pomegranate juice because the pomegranate juice was quite resistant to microbial spoilage at refrigeration temperature due to the presence of the polyphenolic compounds (Cemeroglu, 1977). The most effective method to remove the phenolic compounds in pomegranate juice was the conventional fining with gelatin (300 mg/ l) and bentonite (300 mg/ l) along with PVPP (Alpher *et al.,* 2005) (Fig 2). Vardin and Fenercioglu (2003) clarified the basket pressed juice with gelatin, poly-vinyl-poly-pyrrolidone (PVPP) and natural sedimentation and reported that the phenolic substances were controlled in each clarification method. The most effective method of clarification was the application of 1 g/l gelatin before heat treatment as it reduced the phenolic substances to an acceptable level, decrease turbidity, preserved anthocyanins and colour density. In order to reduce the amount of tannin in pomegranate juice, Bayindirli *et al.* (1994) found the addition of 2g/l gelatine as the most effective method of clarification which resulted in the clear and rich coloured juice as compared to the natural clarification which gave turbid juice. Removal of phenols can be accomplished with the help of filtration methods such as ultra filtration. Neifar *et al.* (2009) investigated that the laccase enzyme application to pomegranate juice resulted in the 40 percent reduction of the total phenol but induced a threefold decrease of juice clarity. This drawback was overcome by the ultra filtration of laccase treated juice giving clear and stable pomegranate juice. Pectinases play a crucial role in clarification, extraction, in reduction of viscosity, to remove off peels and to increase the yield of fruit juices. The use of pectinase enzyme for the clarification of the fruit juices by depectination is reported by many authors (Vilquez *et al.,* 1981; Song-nian *et al.,* 2011)

6.3 Packaging of Pomegranate Juice

Packaging material selection as well as processing influences the quality of foods, altering colour and nutrient composition during storage as a result of contact with oxygen and light transmission through them. Paperboard cartons with low density polyethylene (LDPE) coating or glass containers are commonly used materials of juices. Oxygen and light have destructive effect on the anthocyanin during storage. So the packaging material also plays an important role in the colour stability of stored pomegranate product. Perez-Vicente *et al.* (2004) assessed the influence of packaging material on colour and bioactive compounds of pasteurized pomegranate juice during storage at 24/18 ^{0}C and 40-50% RH. They opined that the organoleptic quality of juice could be altered by packaging material, even if nutritional quality is not influenced suggesting that the oxygen permeability of the packaging material (which is the more damaging factor than light for pomegranate juice) should be minimized to avoid the detrimental effects on the retention of colour and some bioactive compounds. Glass containers were found to be better as compared to high density polyethylene or polyvinylchloride containers with regards to retention of anthocyanins, vitamin C and organoleptic quality of the fruit juices (Sethi, 1985). Wasker and Deshmukh (1995) studied the effect of light on the quality of stored pomegranate juice. The results showed that pomegranate juice packed in amber coloured glass bottle retained better anthocyanins as compared to juice packed in colourless bottles.

6.4 Storage of Pomegranate Juice

The numbers of factors are affecting the stability of the coloured pigments like anthocyanin in the pomegranate juice includes temperature, oxygen, light, pH, enzymatic action etc. Out of these, the storage temperature is the important one. Many researchers have reported that the pomegranate juice can be successfully stored at ambient temperature as well as in cold storage (5±1^{0}C). But the better retention of anthocyanins and reduction in the enzymatic activity of pomegranate juice was reported in the pomegranate juice stored in cold storage. Ahire (2007) reported that the hand pressed or mechanical pressed pomegranate juice packed in the glass bottles could be stored satisfactorily upto 3 months under cold storage (5±1^{0}C) conditions with higher acceptable organoleptic score. The pomegranate juice can be stored up to 60 days at room temperature with the minimum changes in TSS, acidity, pH, total sugar, reducing sugars and tannin when pasteurized at 70^{0}C and added 500 ppm sodium benzoate (Suryawanshi *et al*., 2008). Adam and Ongley (1972) reviewed the beneficial influence of low temperature storage on various pigmented fruit products. They observed that, bottling of fruits at low pH (between 1-2), without adding sugar, led to small but significant increase in the pigment stability. Especially when stored at ambient (35°C) the pigment degradation was faster. An increasing trend in TSS, pH, reducing sugars, non-reducing sugars and total sugars during three months storage of pomegranate juice based carbonated beverage both at ambient and in cold temperature storage was reported by Shelar (2001) and Sandhan (2003).

7. Minimally Processed (Ready To Eat) Pomegranate Products

7.1 Fresh Pomegranate Arils

As earlier discussed, tedious, difficult and time consuming procedure in the preparation of the arils, makes the pomegranate fruit unpopular as a table fruit. It is for these reason that the development of 'ready – to-eat pomegranate arils has been a challenge that has been approached by several research groups in Spain (Artes *et al.,* 1995) and the USA. In recent years, minimally processed "ready-to-eat" pomegranate arils have become popular due to their convenience, high value, unique sensory characteristics and health benefits. James Caleb *et al.* (2011) reported that with increasing global interest in postharvest handling and nutritional value of pomegranate, MAP of minimally processed pomegranate arils offers additional tool for optimal use and value addition, including the utilization of the lower grade fruits with superficial peel defects like cracks, splits, sun burnt and bacterial blight. Maintaining the nutritional and microbial quality of pomegranate arils is a major challenge as the minimally processed arils easily deteriorate in texture, colour, overall quality and a reduction in shelf life (Gil *et al.,* 1996a-b). Minimal processing of pomegranate mainly consists of washing with the sanitizing agents to reduce the initial microbial load, pH modifications, use of antioxidants, modified atmosphere packaging and temperature control. (Sepulveda *et al.,* 2000) (Fig 3) The best results with the cultivar 'Mollar de Eche' were obtained washing the arils with the chlorine solution, followed by a mixture of ascorbic and citric acids and storing the seeds at 1^{0}C in polypropylene films that allowed the formation of a modified atmosphere appropriate for the conservation of these arils. The preparation of the arils under very clean conditions and at temperatures close to 0^{0}C prolonged the life of this product and maintained its quality (Gil *et al.,* 1996a). Storage at the higher temperatures (4-8^{0}C) produced the product with lower quality and a shorter commercial life. The novel technologies such as smart packaging offers potential of increase in the shelf life of pomegranate arils by ensuring the microbial safety and monitoring the storage temperature with TTI. Also, the use of natural or non destructive products as preservatives (such as honey and UV-C radiation) should be done in combination with MAP (James Caleb *et al.,* 2011). Ayhan and Esturk (2009) found that the pomegranate arils packed with air, nitrogen and enriched oxygen kept acceptable quality attributes on 18th day, however, marketability period was limited to the 15th day for the low oxygen atmosphere. Lopez-Rubira *et al.* (2005) studied the effect of harvest time, use of different UV-C radiation and passive MAP with polypropylene basket sealed with BOPP film storage on sensory, chemical and microbial quality as well as on the shelf life of minimally fresh processed pomegranate var. Mollar de Elche arils. They observed that the rate of respiration of fresh processed arils was higher in the late harvest than in the earlier harvested fruits. No significant differences were observed between the control and UV-C treated arils and there was no observable interaction between passive MAP and UV-C treatment, except that the CO_2 accumulation within aril packages was higher in December harvest than those of October, due to their respiration rate. They reported that unclear results were obtained on the effect of UV-C radiation on the microbial growth of pomegranate arils and the shelf-life of commercially produced pomegranate arils can be increased up to 10 days with use 100 % nitrogen in pet packages. No significant change in the total anthocyanin content of arils was observed. They also reported that the microbial counts of minimally fresh processed arils -

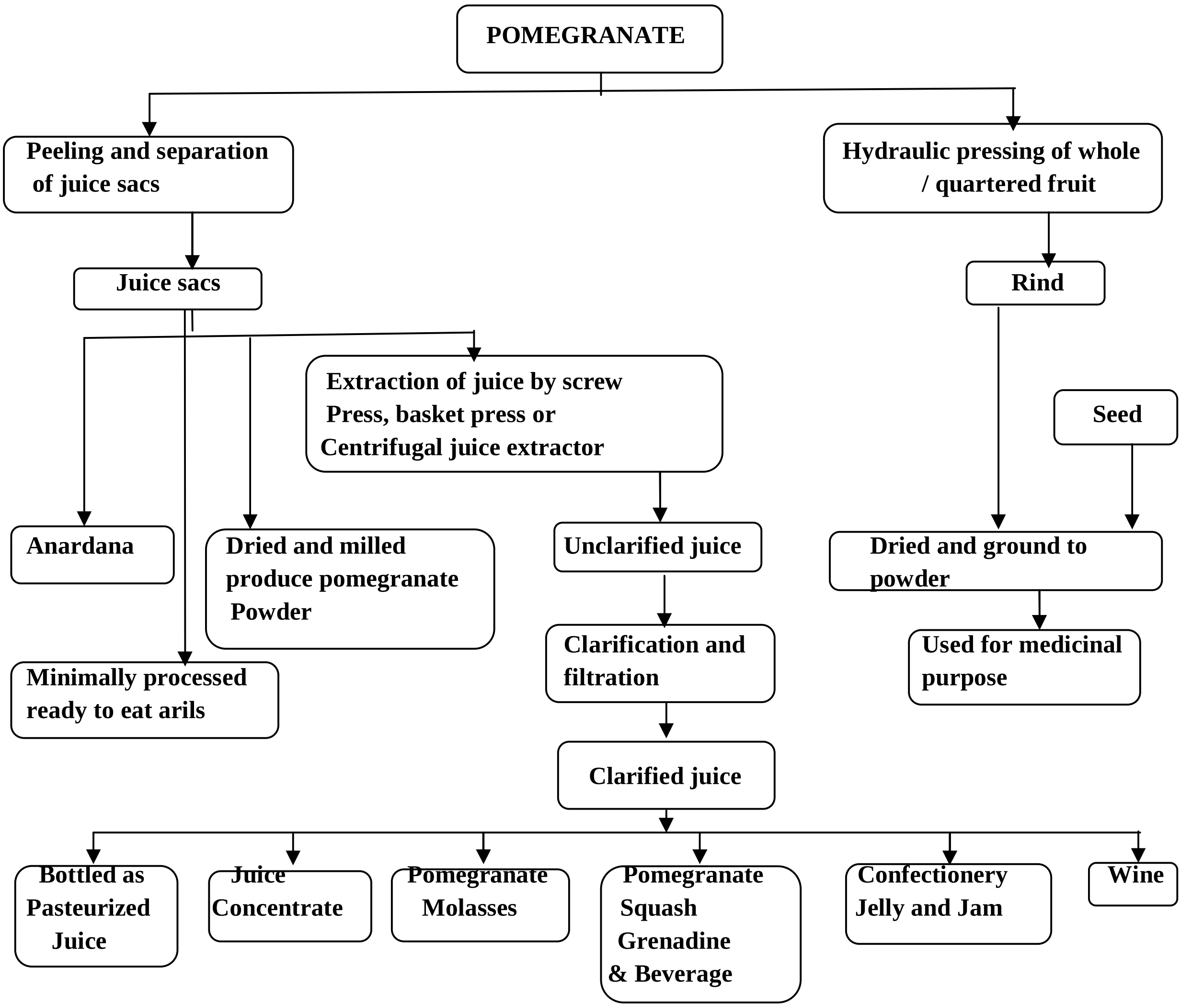

Fig 1: Utilization of pomegranate for industrial processing: A flow Chart (Source: Yadav *et al.,* 2006).

increased throughout the shelf life, with mesophilic counts of control arils processed in October slightly higher than those from December. A low count of micro-aerophilic lactic acid bacteria after 10 days of aril storage without any trace of fermentative metabolism was also recorded.

Nunes *et al.* (2010) investigated the metabolic response of the minimally processed pomegranate arils cv. Hicanar to UV-C treatments and stored at 2^0C and 6^0C. They observed that the UV-C illumination had an effect on the increase of phenol content in pomegranate arils but TSS and citric acid percentage remained unaffected.

Gil *et al.* (1996b) reported that the pomegranate arils of Mollar variety washed with chlorinated water (100mg/kg) and antioxidants solution (5g/l ascorbic acid and 5g/l citric acid), packed in OPP film, using an initial atmosphere actively modified to 0ml/l CO_2 and 20ml/l O_2 and stored at 1^0C, can be stored up to 7 days maintaining a good quality and appearance, without visible attack of moulds or off flavour developments. Sepulveda *et al.* (2001) investigated that pomegranate arils cv. Espanola washed and immersed in antioxidant solution (sodium hypochlorite, 200 ppm, 5% ascorbic acid and 5% citric acid) for 1 minute and stored at 5 ± 0.5^0C in three semi-permeable packaging can be stored for 7 days with commercial marketable acceptance. BB4 bags showed the best ability to maintain the physical, chemical and microbiological characteristics of the minimally processed pomegranate arils, but the sensory characteristics decreased from 7 to 14 days storage. Palma *et al.* (2009) during his -

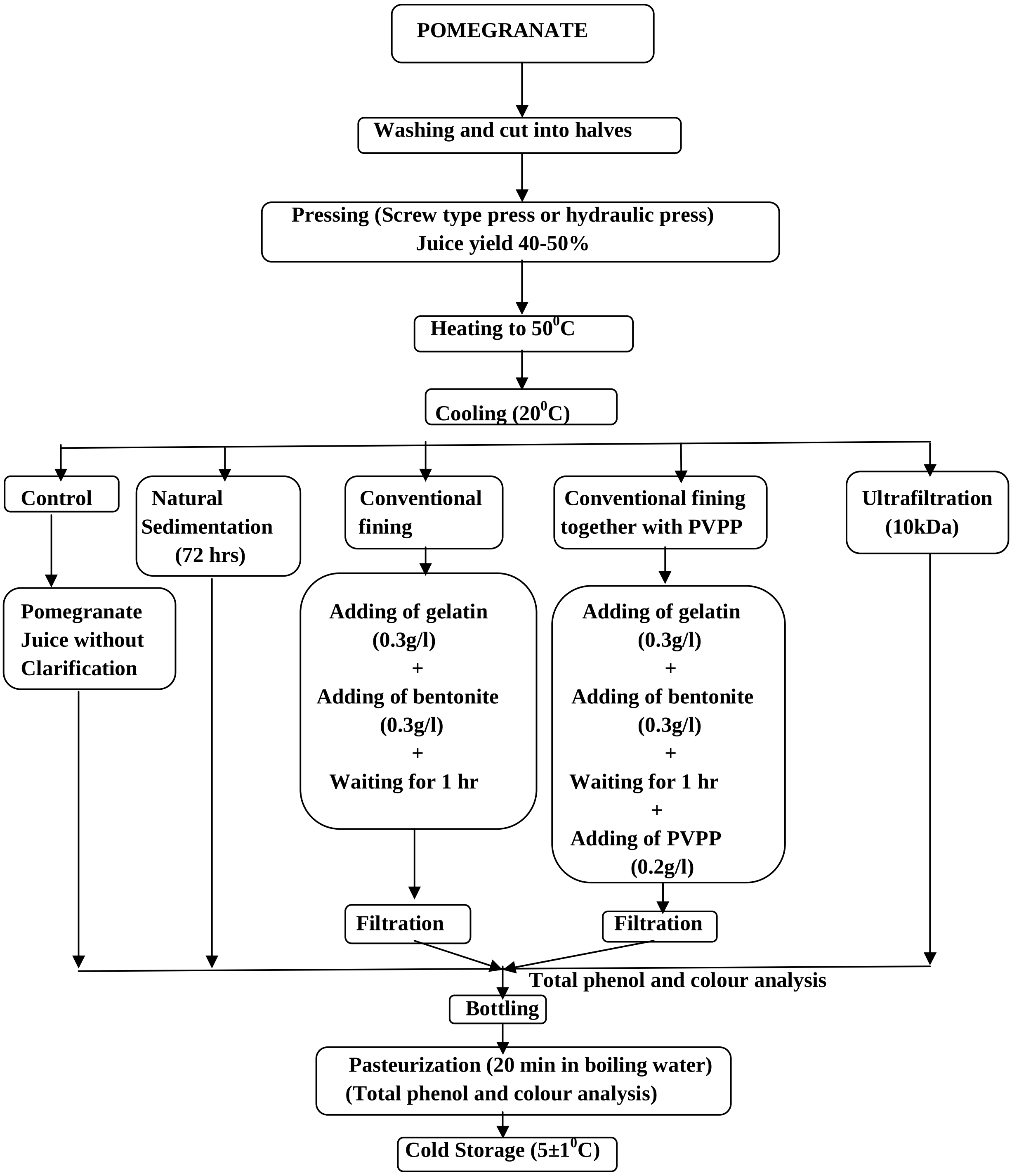

Fig 2: Flow diagram of pomegranate juice processing technology: Use of different clarification techniques (Source: Alper *et al.*, 2005)

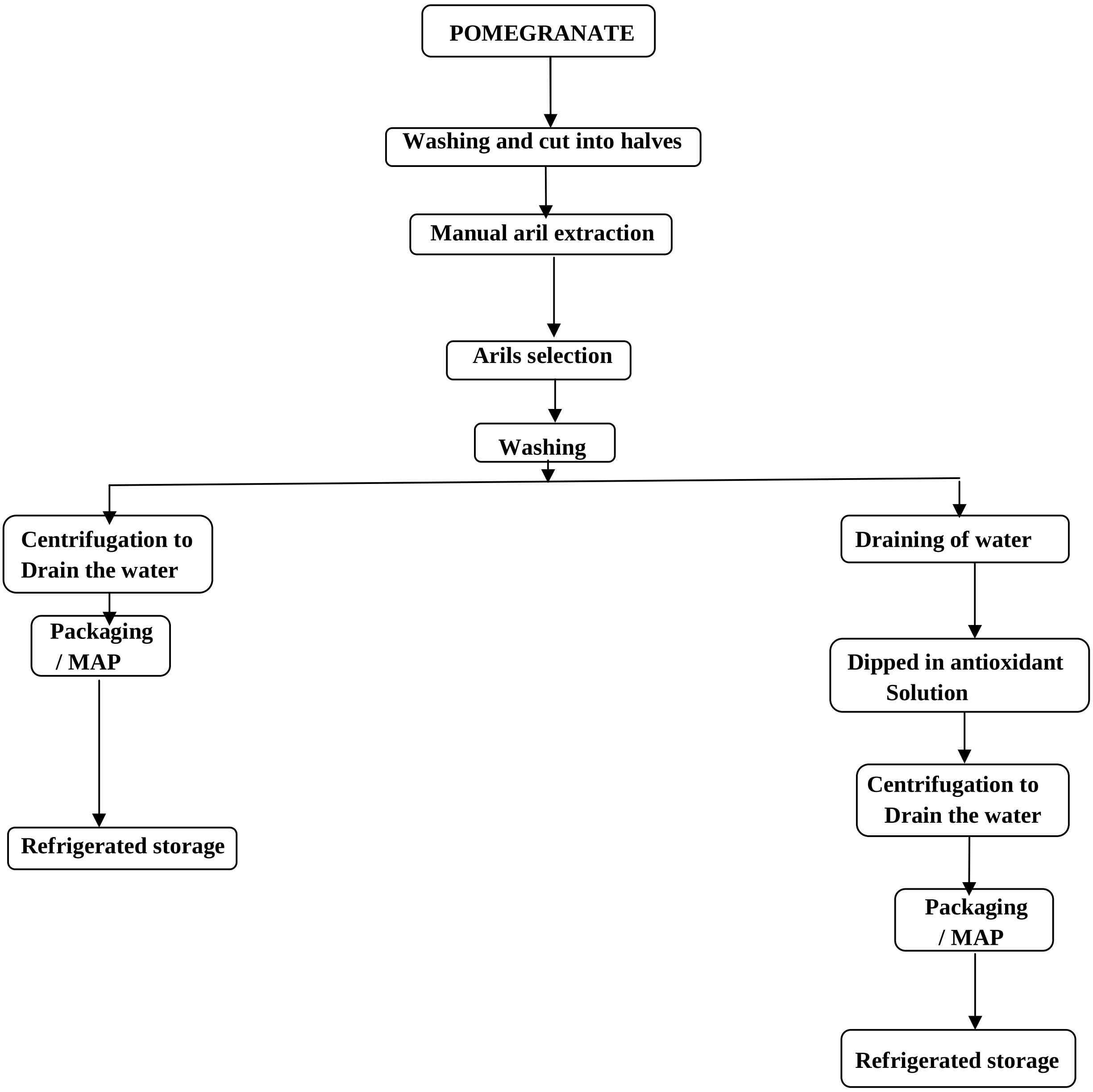

Fig 3: Flow diagram of minimal processing of pomegranate arils (Source: Sepulveda *et al.*, 2000)

studies on the chemical and organoleptic characteristics of minimally processed seeds of pomegranate cv. Primosole, packed in a 40 µm thick polypropylene film, stored at 5^0C for 10 days observed that a passive modified atmosphere was established within the package, with a progressive increase in CO_2 and decrease in O_2 level, with increased ethylene concentration at the end of the storage. No significant changes in chemical properties were recorded, but increase in titratable acidity was observed in packaged seeds. Hess-Pierce and Kader (1997) concluded that arils of '*Wonderful*' pomegranate can be stored upto 16 days at 5^0C with 20 per cent gas composition of CO_2 without changes in the physical and chemical characteristics of the fruit. Further they also observed the susceptibility of the mechanically damaged arils to moulds after 12 days.

Ersan *et al.* (2010) studied the effect of CO_2 and O_2 on the respiration rate of pomegranate arils cv. Hicaz and evaluated the suitability of the common packaging material for designing the MAP. They reported that the respiration rate of the arils was significantly affected by O_2 and CO_2 concentrations in the surrounding atmosphere. Lower respiration rate was achieved in 2 per cent O_2 with 10 or 20 per cent CO_2 but MAP design analysis indicated that these target levels of O_2 and CO_2 cannot be achieved by LDPE and PP materials for commercial packages. The storage atmosphere enriched in CO_2 (10, 15 and 20 %) helped to prolong the commercial life of pomegranate seeds upto 8 days at 10^0C and 12 days at 5^0C (Artes and Tomas-Barberan, 2000).

The use of honey treatments has also been explored in preserving the fresh-like quality of arils, other cut fruits and to extend their shelf life. Honey has been used since ancient times as a sweetening agent in food and is only the concentrated form of sugar available worldwide. Ergun and Ergun (2009) evaluated the efficacy of varying concentration of 10 and 20 per cent honey dip treatment on the quality and shelf life of minimally processed pomegranate arils cv. Hicaznar stored at 4^0C in loosely closed containers. They reported that honey solution (10 and 20 per cent) dipping for five minutes can help in storage of arils at 4^0C for 10 days with brilliant aroma than those treated with water. It also helped in the lowering the softening of the arils. The total aerobic count was lower in honey treated arils compared with the control but the counts increased across all the treatments compared with the count immediately after treatment. It extended the fresh-like quality of arils by delaying quality loss, microbial development and pigment changes, thus providing the safe organic method.

A summary of MAP of pomegranate arils, different cultivars, highlighting the types of the packaging adopted and the modified atmosphere condition attained in the packages is reviewed in Table 4.

7.2 Frozen Arils

After preparing the arils same as that of minimally processed arils, the arils were packed in the polyethylene bags with syrup of 15^0Brix. This concentration is similar to that of the arils. The arils were then frozen in a chest freezer. The juice contain of aril enters the syrup during freezing. Maestre *et al.* (2000) also reported the freezing of the arils coated with the sugar. The coated sugar turned red during freezing and storage. The arils should be eaten frozen to avoid an excessive loss of turgence.

7.3 Appertised Arils

Appertised arils are the product prepared by putting the arils in syrup of 15^0 Brix and packed into metal tin. The tins were heated, sealed and sterilized for 10 minutes. After stabilization, most of the tins had arils that were too soft and that tasted cooked. The tins which were prone to less severe heat treatment had adequate textured arils with good taste.

7.4 Arils in Vinegar

The arils were preserved in vinegar with an acidity of 5% and packed in jar. The resultant product was the brown coloured pomegranate arils.

7.5 Jams and Preserves (Anar Rub)

A product known as *anar rub* with fairly good keeping quality can be made be concentrating pomegranate juice and heating the mixture on a slow fire for long period. The finished product has a thick consistency and contains 70-75% TSS (Siddappa and Bhatia, 1954). It can be stored for one year and utilized as a jam. Maestre *et al.* (2000) reported that the jams and preserves made from the frozen Mollar pomegranate juice by 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, depending on the temperature than on light. The best preservation temperature reported was 5 ^{0}C.

7.6 Jellies

An attractive jelly can be prepared from pomegranate juice (Phadnis, 1974). Adsule *et al.* (1992) prepared good pomegranate jelly on a small scale from Ganesh cultivar of pomegranate. While making jellies, approximately 50% of the anthocyanins present in pomegranate juice were lost. Maestre *et al.* (2000) investigated that the acidification of juice produced a noteworthy improvement in the colour of jelly, both initially and during storage. During storage, certain colour differences were observed, which indicates that the pH was not only the parameter responsible for this characteristic.

7.7 Anardana

Anardana is dried arils from sour wild types. It is mainly used as acidulent in place of tamarind of dried green mango (Amchur) in North India in Indian styled curries, chutney and other culinary preparations. It is also used in the preparation of digestive candies and by traditional system of Ayurvedic and Unnani medicine. The improved processing technique consists of pre cleaning, mechanized extraction of arils, solar/ sun drying and packaging. After trating with sodium benzoate (600 ppm) for 10 minutes, arils are dehydrated in a drier at 45^{o}C for 48 hrs to 10-12% moisture content. It has attractive brown colour and can

Table 4: Summary of modified atmosphere packaging of pomegranate arils, different cultivars, types of packaging film, modified atmosphere composition with temperature and duration of storage under MAP (Source: James Celeb *et al.*, 2011)

Type of product	Package film	MA composition		Storage temp. (^0C)	Storage period	References
		$\%O_2$	$\% CO_2$			
Pomegranate arils cv. Mollar de Elche	Oriented polypropylene (OPP)	188ml/l $OPP-CO_2$ $OPP-N_2$	22ml/l 206ml/l 203ml/l	1 3ml/l 4ml/l	7 days	Gil *et al.*, 1996
Pomegranate arils cv. Mollar	Semi-permeable plastic bag	1	30	4	10 days	Garcia *et al.*, 2000
Pomegranate arils cv. Mollar de Elche	OPP, 40 µm thickness	12.5 13.5 18.5	8.5 7.5 2.5	8 4 1	7 days	Gil *et al.*, 1996a
Pomegranate arils cv. Mollar de Elche	Polypropylene basket sealed with BOPP (October) Polypropylene basket sealed with BOPP (December)	2-5kPa 2-5kPa	20.1-21.6 kPa 26.9-29.9 kPa	5	15 days	Lopez-Rubira *et al.*, 2005.
Pomegranate arils cv. Wonderful	BB4 (cryovac based on ethyl vinyl acetate) BE (cryovac based on ethyl vinyl acetate) Perforated polyethylene bags	1 12 Not reported	22 2	4	14 days	Sepulveda *et al.*, 2000.
Pomegranate arils cv. Primosole	Polypropylene	6.5	11.4	5	10 days	Palma *et al.*, 2009.

be stored for a long time in glass jars (Anonymous, 2005).

7.8 Pomegranate Molasses

It is traditional Middle Eastern ingredient made from cooked down pomegranate juice. Thick and syrupy in texture, pomegranate molasses provide tangy flavor and is dark in colour. Its sweetness comes from the concentration of the fruits natural sugars (Yadav *et al.*, 2006). To make ½ cup of molasses, 4 cups of juice is heated in a pan for 45 minutes, allowing it to thicken but not overcooked. The product can be stored in air tight container under refrigerated conditions for 3 months. It is typically used to flavor chutneys, curries and salad dressings to glaze or tenderize meat products.

7.9 Pomegranate Concentrate

The commercially available pomegranate juice concentrate generally contains 65-70% TSS and pH 2.7 to 3.1. It is made from natural pomegranate juice and it is generally free from any added sugar or preservative. Most of the companies in international market are promoting it as health drink giving stress on the medicinal and health benefits of pomegranate. Maskan (2006) described the different processes for the preparation of pomegranate concentrate of 60.5°Brix by using microwave, rotary vacuum and atmospheric heating processes method in 23, 108 and 190 min respectively. Hulya Orak (2009) recorded increase in the reducing sugars, glucose and fructose level to 46.46%, 23.89% and 22.53%, respectively during the conventional method of pomegranate juice concentration process. Also the potassium and magnesium mineral contents of concentrate increased during concentration.

7.10 Pomegranate Syrup / Grenadine

Pomegranate syrup is sold commercially as grenadine and is used as flavoring in alcoholic drinks, soft drinks and confections. Grenadine is light pomegranate syrup prepared by mixing juice and sugar. A syrup of about 60^{o}Brix with an added acidity of 1.5% as citric acid has a bright purplish red colour and a delightful taste and flavor. It can be preserved by pasteurization or by addition of sodium benzoate.

7.11 Pomegranate Beverages

Pomegranate can be processed into delicately flavoured RTS beverage, blend and squash. Squash is prepared with 40% juice and RTS beverage and beverage blends with 15% juice content. Squash is ready to serve in the ratio of 1:4 (one part of squash with 4 parts of water).

7.12 Confectionery

Phadnis (1974) reported preparation of jelly and hard candy from pomegranate. Researchers have found that approx. 50% of total anthocyanin present in the juice is lost during jelly preparation and the acidification of juice improves the colour in the final product. Anar Rub (Pomegranate jam) is prepared from juice by adding sugar and heating to a thick consistency.

7.13 Wine

Pomegranate juice can be utilized to make good quality wine. Sugar is added to adjust Brix to 22-23^{O}. The pasteurized juice is fermented with starter wine yeast. The fermentation is allowed to continue until desired level of alcohol is obtained. The wine is clarified by bentonite treatment or by centrifugation. The wine aged in the same manner as red grape wine.

7.14 Pomegranate Powder

Low moisture pomegranate powder is prepared from pomegranate arils that have been dried and milled. The active ingredient considered in pomegranate powder is ellagic acid. The freeze dried pomegranate powder rich in ellagic acid have many applications and may be encapsulated for regular doses (Donald, 2005). Husain *et al.* (2004) have proposed grade standards to bring the commodity under the purview of AGMARK certification.

8. Pomegranate Waste Utilization

All parts of the pomegranate tree i.e. roots; bark, leaves, flowers, rind and seeds can be processed for value added products having medicinal, industrial and cosmetic value. Technology for preparation of rind powder has been developed, having potential uses in medicine, leather and dye industry and in tooth powder preparation. The recovery of rind powder has been found to be 15.5% on whole fruit basis and 34 % on rind weight basis.

As a part of pomegranate industrialization, the field of pomegranate by-products is an interesting field to be exploited as it is a rich source of alkaloids, aromatic compounds and enzymes.

9. Conclusion

The pomegranate fruit is considered as the suitable fruit for the processing and utilization due to its excellent flavour, colour, physico-chemical constitution and therapeutic properties. It is referred as the 'Superfruit' due its high nutritional value, high antioxidant capacity and consumer appeal. But in spite of high nutraceutical value, the consumption of pomegranate is not wide spread due to tedious and time consuming peeling and irritations and staining of hands during handling of fruits. The pomegranate processing and product diversification has played important role in the increased consumption and utilization of pomegranate. Last few years, the research and development activities on pomegranate fruit have aimed to develop technologies for new pomegranate derived food products. The pomegranate can be processed into products like minimally processed fresh arils, juice, squash, beverage, molasses, juice concentrates, frozen seeds, jam, jelly, marmalades, grenadine, wine, seeds in syrup, pomegranate spirits, pomegranate powder, pomegranate rind powder, anardana, confectionery, pomegranate seed oil etc. These products are not yet popularized in large scale due to lack of the commercially viable processing technologies. The keen and immediate attention is required in meeting the research and developmental gaps for the commercialization and popularization of pomegranate processing technology and pomegranate products. The major aspects which requires immediate attention in pomegranate processing includes industrial method of peeling, standardization of extraction and proper clarification methods of pomegranate juice, development of standards for packaging and storage of pomegranate derived products, application of the new inline technologies such as MAP, ultra filtration for pomegranate utilization and popularization of pomegranate based products.

Hence, for the commercialization and utilization of pomegranate processing technology and pomegranate products, experimental studies should be carried out with more informative output on the metabolic properties of pomegranate and derived products under various conditions in order to develop the scientific database and to enable the successful application of the available technology.

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