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REVIEW

Chemical composition, functional properties and processing of carrot—a review

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Abstract Carrot is one of the important root vegetables rich in bioactive compounds like carotenoids and dietary fibers with appreciable levels of several other functional components having significant health-promoting properties. The consumption of carrot and its products is increasing steadily due to its recognition as an important source of natural antioxidants having anticancer activity. Apart from carrot roots being traditionally used in salad and preparation of curries in India, these could commercially be converted into nutritionally rich processed products like juice, concentrate, dried powder, canned, preserve, candy, pickle, and *gazrailla*. Carrot pomace containing about 50% of β-carotene could profitably be utilized for the supplementation of products like cake, bread, biscuits and preparation of several types of functional products. The present review highlights the nutritional composition, health promoting phytonutrients, functional properties, products development and by-products utilization of carrot and carrot pomace along with their potential application.

Keywords Carrot · Carotenoids · Dietary fiber · Antioxidants · Pomace · Functional products

Carrot *(Daucus carota* L) is one of the popular root vegetables grown throughout the world and is the most important source of dietary carotenoids in Western countries including the United States of America (Block 1994; Torronen et al. 1996). China is the major carrot producing country in the world (FAO 2008). The area under carrot in India is 22,538 ha with an annual production of 4.14 lakh tons (Thamburaj and Singh 2005) with Uttar Pradesh, Assam, Karnataka, Andhra Pradesh, Punjab and Haryana being the major producing States. In recent years, the consumption of carrot and its products have increased steadily due to their recognition as an important source of natural antioxidants besides, anticancer activity of β-carotene being a precursor of vitamin A (Dreosti 1993; Speizer et al. 1999).

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Chemical composition

The moisture content of carrot varies from 86 to 89% (Anon 1952; Howard et al. 1962; Gill and Kataria 1974; Gopalan et al. 1991). Carrots are a good source of carbohydrates and minerals like Ca, p, Fe and Mg. Gopalan et al. (1991) have reported the chemical constituents of carrot as moisture (86%), protein (0.9%), fat (0.2%), carbohydrate (10.6%), crude fiber (1.2%), total ash (1.1%), Ca (80 mg/100 g), Fe (2.2 mg/100 g) and p (53 mg/100 g) whereas, the values reported by Holland et al. (1991) for most of these parameters are different i.e. moisture (88.8%), protein (0.7%), fat (0.5%), carbohydrate (6%), total sugars (5.6%), crude fiber (2.4%), Ca (34 mg/100 g), Fe (0.4 mg/100 g), p (25 mg/100 g), Na (40 mg/100 g), K (240 mg/100 g), Mg (9 mg/100 g), Cu (0.02 mg/100 g), Zn (0.2 mg/100 g), carotenes (5.33 mg/100 g), thiamine (0.04 mg/100 g), riboflavin (0.02 mg/100 g), niacin (0.2 mg/100 g), vitamin C (4 mg/100 g) and energy value (126 kJ/100 g). The edible portion of carrots contains about 10% carbohydrates having soluble carbohydrates ranging from 6.6 to 7.7 g/100 g and protein from 0.8 to 1.1 g/100 g in 4 carrot cultivars (Howard et al. 1962). Kaur et al. (1976) have reported 1.67–3.35% reducing sugars, 1.02–1.18% non-reducing sugars and 2.71–4.53% total sugars in 6 cultivars of carrot. Simon and Lindsay (1983) reported that reducing sugars accounted for 6–32% of free sugars in 4 hybrid varieties of carrot. The free sugars identified are sucrose, glucose, xylose and fructose (Kalra et al. 1987). The crude fiber in carrot roots consist of 71.7, 13.0 and 15.2% cellulose, hemicllulose and lignin, respectively (Kochar and Sharma 1992). The cellulose content in 4 carrot varieties varied from 35 to 48% (Robertson et al. 1979). The average nitrate and nitrite content in fresh carrot have been 40 and 0.41 mg/100 g, respectively (Bose and Som 1986; Miedzobrodzka et al. 1992). The taste of carrots is mainly due to the presence of glutamic acid and the buffering action of free amino acids. Trace amounts of succinic acid, α-ketoglutaric acid, lactic acid and glycolic acid have also been reported (Kalra et al. 1987). Caffeic acid is the predominant phenolic acid in carrots. Thiamin, riboflavin, niacin, folic acid and vitamin C are present in appreciable amounts in carrot roots (Howard et al. 1962; Bose and Som 1986). The anthocyanins content in roots may vary from trace amounts in pink cultivars to 1,750 mg/kg in black carrots (Mazza and Minizte 1993). The major anthocyanins have been identified as cyanidin 3- (2-xylosylgalactoside), cyanidin 3-xylosylglucosylgalactoside and cyanidin 3-ferulylxyloglucosyl galactoside (Harborne 1976).

Phytonutrients

Plant components, primarily secondary metabolites that have health promoting properties are called phytonutrients. The importance of antioxidant constituents in the maintenance of health and protection from coronary heart disease and cancer is raising considerable interest among scientists, food manufacturers and consumers as the trend of the future is moving toward functional food with specific health effects (Velioglu et al. 1998; Kahkonen et al. 1999; Robards et al. 1999). In vitro studies indicated phytonutrients such as carotenoids and phenolics may play a significant role, in addition to vitamin in protecting biological systems from the effects of oxidative stress (Kalt 2005). Carrot is a significant source of phytonutrients including phenolics (Babic et al. 1993), polyacetylenes (Hansen et al. 2003; Kidmose et al. 2004) and carotenoids (Block 1994). Carrot is rich in β-carotene, ascorbic acid and tocopherol and is classified as vitaminized food (Hashimoto and Nagayama 2004). Due to appreciable level of variety of different compounds present, carrots are considered as a functional food with significant health promoting properties (Hager and Howard 2006).

Carotenoids The importance of carotenoids in food goes beyond as natural pigments and biological functions and actions have increasingly been attributed to these pigments. Carotenoids are present intracellularly and their actions involve in the regulation of gene expression or effect cell functions like inhibition of monocyte adhesion and platelet activation (Rock 1997). These biological effects are independent of the pro-vitamin A activity and have been attributed to the antioxidant property of carotenoids, through deactivation of free radicals and singlet oxygen quenching (Krinsky 1989; Palozza and Krinsky 1992). In general, carotenoids in foods are classified into carotenes and xanthophylls, which give attractive red or yellow colour and contribute to food quality. Structurally, the carotenoids may be acyclic or contain a ring of 5 or 6 carbons at one or both ends of the molecule (Carle and Schiber 2001).

Carotenoids are important micronutrients for human health (Castermiller and West 1998). The total carotenoids content in the edible portion of carrot roots range from 6,000 to 54,800 μg/100 g (Simon and Wolff 1987). The main physiological function of carotenoids is as precursor of vitamin A (Nocolle et al. 2003). In the past decade carotenoids such as β-carotene have attracted considerable attention because of their possible protective effect against some types of cancers (Bast et al. 1996; Santo et al. 1996; Van 1996). In human system, the physiological activity of α- and β-carotene has been 50 and 100% of the provitamin A activity, respectively (Panalaks and Murray 1970; Simpson 1983) and one molecule of β-carotene (Fig. 1) yields two molecules of retinol in human system. Carotenoids (Fig. 2) have been linked with the enhancement of immune system and decreased risk of degenerative diseases such as cancer, cardiovascular disease, age related mascular degeneration and cataract formation (Mathews-Roth 1985; Bendich and Olson 1989; Bendich 1990; Krinsky 1990; Byers and Perry 1992; Bendich 1994; Krinsky 1994; Faulks and Southon 2001). Carotenoids have been identified as a potential inhibitor of Alzheimer's disease (Zaman et al. 1992).

The presence of high concentration of antioxidant carotenoids especially β-carotene may account for the biological and medicinal properties of carrots. Carrots have been reported to have diuretic, N-balancing properties and are effective in the elimination of uric acid (Anon 1952). Numerous animal experiments and epidemiological studies have indicated that carotenoids inhibit carcinogenesis in mice and rats and may have anticarcinogenic effects in humans. In biological systems, β-carotene functions as a free radical-trapping agent and single oxygen quencher and have antimutagenic, chemopreventive, photoprotective and immunoenhancing properties (Deshpande et al. 1995).

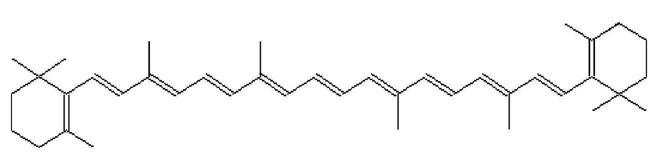


Fig. 1 Structure of β-carotene

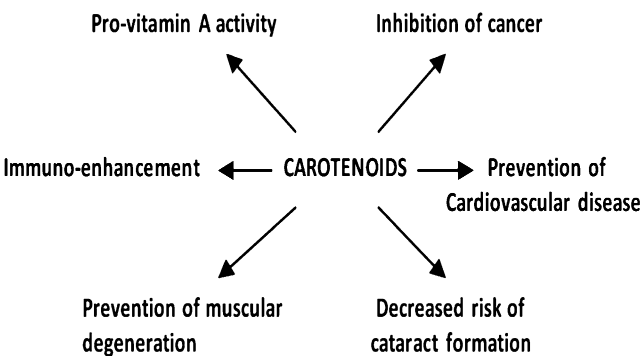


Fig. 2 Health promoting functions attributed to carotenoids

Carrot intake may also enhance the immune system, protect against stroke, high blood pressure, osteoporosis, cataracts arthritis, heart diseases, bronchial asthma and urinary tract infection (Beom et al. 1998; Sun et al. 2001; Seo and Yu 2003). Carotenoids also act as free-radical scavengers and are very important for health (Bast et al. 1998; Bramley 2000). D'Odorico et al. (2000) have shown that the presence of α- and β-carotene in blood has a protective effect against atherosclerosis. Nocolle et al. (2003) has demonstrated that high carotenoid diets are associated with a reduced risk of heart disease.

Phenolics Phenolics or polyphenols have received considerable attention because of their physiological functions, including antioxidant, antimutagenic and antitumor activities. They have been reported to be a potential contender to combat free radicals, which are harmful to our body and foods systems (Nagai et al. 2003). Although, phenolic compounds do not have any known nutritional function, they may be important to human health because of their antioxidant potency (Hollman et al. 1996). Phenolics are ubiquitous plant components that are primarily derived from phenylalanine via the phenylpropanoid metabolism (Dixon and Paiva 1995). Phenolics in carrots are present throughout the roots but are highly concentrated in the periderm tissue (Mercier et al. 1994). Two major classes of phenolics are hydroxycinnamic acids and para-hydroxybenzoic acids (Babic et al. 1993). Further, Zhang and Hamauzee (2004) have studied the phenolic compounds, their antioxidant properties and distribution in carrot and found that it contained mainly hydroxycinnamic acids and derivatives. Among them chlorogenic acid was a major hydroxycinnamic acid, representing 42.2–61.8% of total phenolic compounds detected in different carrot tissues. The phenolic contents in different tissues decreased in the following order peel > phloem > xylem. Although, carrot peel accounted for only 11% of the amount of the carrot fresh weight, it could provide 54.1% of the amount of total phenolics, while the phloem tissue provides 39.5% and the xylem tissue provides only 6.4%. Antioxidant and radical scavenging activities in different tissues decreased in the same order as phenolic content. These findings suggested that phenolics could play an important role in antioxidant properties in carrots and other hydroxycinnamic derivatives such as dicaffeoylquinic acids and chlorogenic acid. Therefore, the higher level of phenolics and antioxidant properties in carrot peel treated as the waste in the processing industry could be considered for value-added utilization. Oviasogie et al. (2009) have reported that the total phenolic content in carrot is 26.6±1.70 μg/g. Total phenols in violet carrot juice have been reported to be 772±119 mg/l by Karakaya et al. (2001).

Dietary fibers Dietary fiber is an indigestible complex carbohydrate found in structural components of plants. They cannot be absorbed by the body and therefore, have no calorific value however, the health benefits of eating fiber rich diet are immense including prevention of constipation, regulation of blood sugar, protection against heart diseases, reducing high levels of and prevention of certain forms of cancers. Fibers are classified into insoluble and soluble depending upon their solubility. Insoluble fibers consist mainly of cell wall components such as cellulose, hemi-cellulose and lignin and soluble fibers are non-cellulosic polysaccharides such as pectin, gums and mucilage (Yoon et al. 2005). Lineback (1999) has reported that the carrot cell wall is composed of pectin (galacturonans, rhamnogalacturonans, arabinans, galactans and arabinogalactans-1), cellulose (β-4, D-glucan), lignin (trans-coniferyl alcohol, trans-sinapyl alcohol and trans-p-coumaryl alcohol) and hemi-cellulose (xylans, glucuronoxylans β-D-glucans and xyloglucans). Carrots are high in dietary fibers (Bao and Chang 1994) and these fibers play an important role in human health (Anderson et al. 1994) and diets rich in dietary fibers are associated with the prevention, reduction and treatment of some diseases such as diverticular and coronary heart diseases (Anderson et al. 1994; Gorinstein et al. 2001; Villanueva-Suarez et al. 2003). Nawirska and Kwasniewska (2005) have reported the composition of dietary fiber constituents in the fresh carrot on dry weight basis as pectin (7.41%), hemi-cellulose (9.14%), cellulose (80.94%) and lignin (2.48%). Dietary fibers are not only desirable for their nutritional properties but also for their functional and technological properties and because of these they could be used as food ingredients (Thebaudin et al. 1997; Schieber et al. 2001).

Products development

Processing/Canning Carrots are processed into products such as canned, dehydrated, juice, beverages, candy, preserves, intermediate moisture products and *halwa* (Kalra et al. 1987). Firmness is an important quality attribute for canning. Usually tender and small carrots are used for canning. Blanching of diced carrot at 71 °C for 3–6 min results in better quality of canned product than that of done at 87.5 °C for a short time (Ambadan and Jain 1971). Carrots are canned in various forms like diced, halved, quartered or whole. Improvement in the colour and quality of canned carrots by heat treatment and by the use of chemicals has been reported (Chiang et al. 1971; Jelen and Chan 1981; Edwards and Lee 1986; Bourne 1987). Thermal processing increased the amount of carotenoids in products (Edwards and Lee 1986; De Sa and Rodriguez-Amaya 2004). Because raw carrots have tough cellular walls, the body is able to convert less than 25% of their β-carotene into vitamin A. Cooking, however, partially dissolves cellulose-thickened cell walls, freeing up nutrients by breaking down the cell membranes. Several studies report increase in total carotenoids after steam blanching (Howard et al. 1999; Sulaeman et al. 2001; Puuponen-Pimia et al. 2003). Leaching of soluble solids during blanching is the major factor, responsible for apparent increase in carotenoids. Blanching also results in isomerization of carotenoids (Desobry et al. 1998).

A study on the effects of blanching and pre-drying treatments on the stability in carotenoids and anthocyanins rich fruits has revealed that with the increase in blanching temperature and time both of these pigments decreased while pre-drying treatments like, pre-treatment with sodium metabisulphite prevented carotenoids oxidation while orthophosphoric acid showed no effect on their oxidation. Carotenoids are more protected in a system with higher moisture retained by glycerol and sugar (Sian and Ishak 1991). Banga and Bawa (2002) reported that β-carotene content of blanched and unblanched samples increased with increase in drying air temperature whereas, ascorbic acid content decreased. Blanching carrot pulp products gives good colour and improves the colour of carrot juice products (Sims et al. 1993; Bao and Chang 1994). Alteration in carotenoids content during processing has been observed by Chandler and Schwartz (1998) stating that blanching and lye peeling followed by pureeing of sweet potato increased carotenoids content from 4 to 11.9 and 10.4%, respectively while this content decreased in canning (19.7%), dehydration (20.5%) and microwaving (22.7%). Sharma et al. (2000) studied the effect of steam, water and micro-wave blanching on the stability of total carotenoids and found that an apparent increase in total carotenoids (2–25%) was recorded when expressed on dry weight basis and 9.9–10.6% decrease in total carotenoids was recorded when expressed on total insoluble solid basis. Mayer and Spiess (2003) reported that high availability and stability of carotene is achieved in Kintoki carrot products after blanching at high temperature (90 °C) and oxygen free condition. Blanched carrots contain higher β-carotene but lower ascorbic acid than their unblanched counterpart just after drying whereas, non-enzymatic browning was unaffected by blanching (Negi and Roy 2001).

Dehydration Cruess (1958) has described a process for the dehydration of carrots. The carrots are dried to about 10% moisture and transferred to portable finishing bins to complete dehydration at 44.4 °C. The methods of preparation and improvement in colour, taste and flavour of dehydrated carrots have been reported by a number of workers (Feinberg et al. 1964; Stephens and McLemore 1969; Luh and Woodroof 1982; Mudahar et al. 1992). Freeze drying provides dried product with porous structure and little or no shrinkage, better taste retention and on rehydration the food resembling the original (Mellor and Bell 1993). The flavour of freeze dried carrot is better than the air dehydrated products (Kalra et al. 1987), however, main disadvantage of freeze drying is its high cost (Krokida and Philippopoulos 2006). Excellent retention (96–98%) of carotenoids in freeze dried carrots has been noticed (Rodriguez-Amaya 1997). Ambadan and Jain (1971) found that blanching of carrot shreds in 5% sugar solution prior to dehydration not only imparts an attractive color but improves the organoleptic and keeping quality of the product. A *kheer* mix (Fig. 3) has been formulated based on dehydrated carrot, skim milk, sugar and other ingredients (Manjunatha et al. 2003).

Nutritional quality of food supplements based on carrot powder (Fig. 4) and grits have been reported to be good source of crude protein, crude fiber, iron, calcium, β-carotene and dietary fiber (Singh and Kulshrestha 2008). Blanching of carrot before dehydration results in higher retention of β-carotene (Negi and Roy 2001). The evaluation of β-carotene content of dehydrated carrots (Table 1) exhibited that the shreds lost the most β-carotene followed by powder and chops during 3 months storage (Suman and Kumari 2002).

High temperature short time (HTST) processing have been used successfully to retard degradation of carotenoids in processed carrots, with highest destruction of carotenoids in conventional canning (121 °C for 30 min) followed by HTST heating at 120 °C for 30 s, 110 °C for 30 s and acidification plus 105 °C heating for 25 s (Chen et al. 1994, 1995). Apart from isomerization and oxidation in high carotenoid containing fruits and vegetables, carotenoid levels increase during processing. In plant tissues, carotenoids exist in *cis* and *trans* forms and during thermal processing some of the *trans* forms are either lost or converted to *cis* and their derivatives, thereby resulting in overall increase of total carotenoids (Chandler and Schwartz 1998; Dietz et al. 1988).

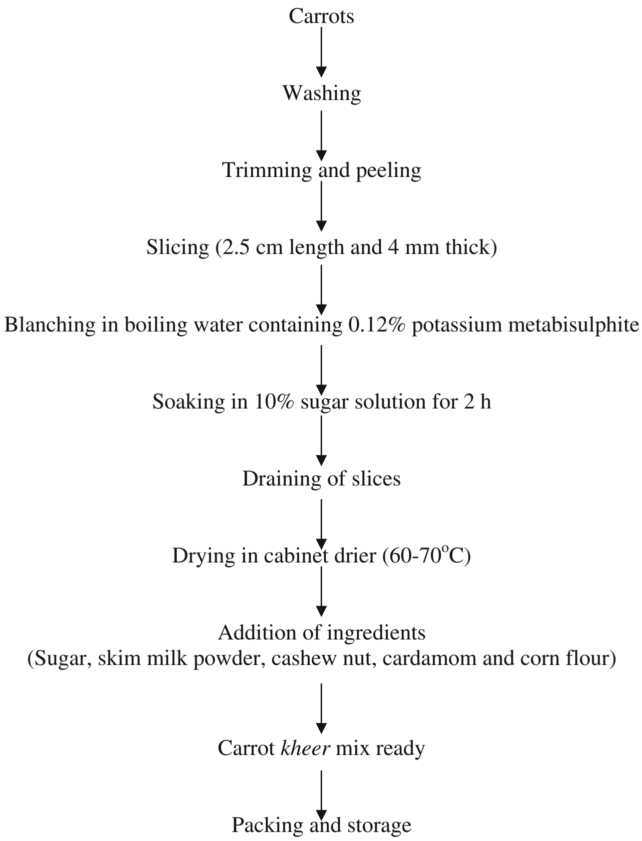


Fig. 3 Steps in the preparation of carrot *kheer* mix

The moisture sorption isotherm studies in carrot revealed that the un-osmosed dehydrated carrot shreds are more hygroscopic as compared to the osmosed dehydrated samples and require a lower relative humidity for safe storage (Singh 2001). The effect of different drying technologies (hot-air drying, vacuum drying, combination drying (hot-air drying + vacuum drying) suggested that the

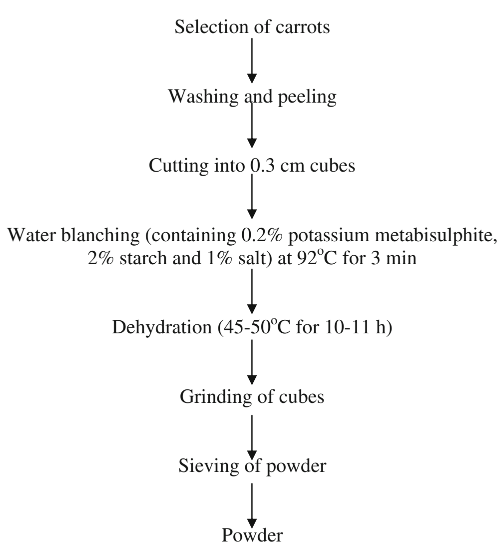


Fig. 4 Steps in the preparation of carrot powder

Table 1 β-Carotene content of dehydrated carrots

	β-Carotene, mg/100 g	Loss of -carotene,%
Fresh carrots	39.6±0.81	–
Dehydrated carrot chops	24.7±0.73	37.0
Dehydrated carrot shreds	22.5±0.68	43.0
Carrot powder	23.9±0.24	40.0

Source: Suman and Kumari (2002)

combination drying technique can keep the carotenoids of carrot well within the short drying time (Zhang-xue et al. 2007). β-Carotene degradation in carrot is comparatively less in vacuum drying and low super heated steam drying as compared to conventional air drying (Suvarnakuta et al. 2005). The degradation of β-carotene is reportedly associated with the development of off-flavours in dehydrated carrots (Ayres et al. 1964; Walter et al. 1970). The activities of carotene degrading enzymes can be decreased by blanching (Reeve 1943). Lipoxygenases are the major enzymes involved in carotene degradation (Kalac and Kyzlink 1980). Dehydrated carrot products like carrot chops, shreds and powder have been utilized for the preparation of recipes like curry, *halva* and biscuits (Suman and Kumari 2002).

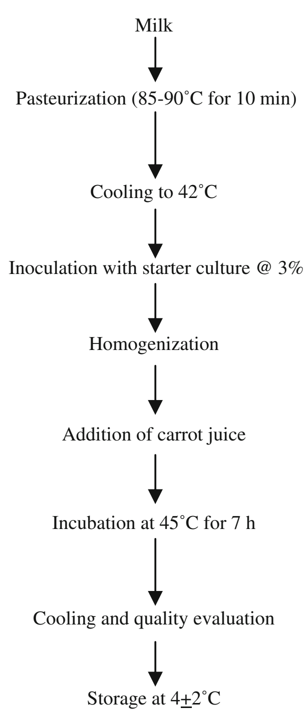
Juice Carrot juice and blends thereof are among the most popular non-alcoholic beverages and steady increase in carrot juice consumption has been reported from various countries (Schieber et al. 2001). Carrot juice and its blends are among one of the most popular non-alcoholic beverages in Germany. Carrot juice is also reported to have its use with other fruit juices in blended form (Stoll et al. 2001). Extraction, canning and storage of carrot juice have been described in detail by various workers (Stephens et al. 1976; Grewal and Jain 1982; Bawa and Saini 1987; Oshawa et al. 1995). Due to low yields associated with carrot juice production, industry is using new technologies for extracting juice such as depolymerizing enzymes, mash heating and decanter technology. Saldana et al. (1976) has developed a carrot beverage by mixing carrot juice with other fruit juices or skim milk. Carrot juice contains high amount of α and β-carotene (Munsch and Simard 1983; Heinonen 1990; Chen et al. 1995; Chen and Tang 1998). It is reported that to reduce the bitterness of 'Kinnow' mandarin juice, blending with carrot juice is a workable option Anonymous (1976). Yield and quality of carrot juice extracted by pressing vary with the pre-treatment condition such as pH, temperature and time (Sharma et al. 2009). The effect of different pre-treatments like blanching solution and blanching times (1–5 min) on the physico-chemical parameters and quality of carrot juice have been studied by Bin-Lim and Kyung-Jwa (1996) and Sharma et al. (2009), respectively. Carrot juice is also used by yoghurt industry (Schieber et al. 2001; Simova et al. 2004). Blending of yoghurt with carrot juice produces a nutritionally rich food (Ikken et al. 1998; Raum 2003). Excellent quality carrot-yoghurt (Fig. 5) could be prepared by blending milk in different proportions having 5–20% carrot juice before fermentation (Salwa et al. 2004).

Pickle Generally, carrots are pickled by lactic acid fermentation. Pruthi et al. (1980) reported that carrots could be preserved in good conditions for 6 months at room temperature even in non air tight containers using acidified brine with potassium metabisulfite and the product can be used for the manufacture of good quality pickles.

Preserve Carrot candy or preserve can be prepared by covering small whole carrots or slices of carrots with sugar or heavy sugar syrup so that total soluble solids content increases to 70–75°B (Beerh et al. 1984). Carrots have been processed to obtain intermediate moisture foods containing about 55% moisture (Jayaraman and Dasgupta 1978; Bhatia and Mudhar 1982; Sethi and Anand 1982). Sethi and Anand (1982) prepared intermediate-moisture carrot slices using a solution containing sugar, glycol, water, acid and preservative. The processed product had good colour, flavour and texture. At low temperatures (1–3 °C), the ready to serve product remained acceptable for 6 months in a glass container with β-carotene retention of 40%.

Carrot cake/Halwa/Gajrailla Processing and preservation of numerous sweet products from carrot have been reported (Sampathu et al. 1981; Beerh et al. 1984; Kalra et al. 1987). Carrot *halwa* is one of the popular sweet dishes of Northern India. Carrot *halwa* is prepared by cooking shredded carrots with sugar and moderately frying in hydrogenated oil or milk fat and milk powder (Sampathu et al. 1981).

Fig. 5 Steps in the preparation of carrot yoghurt



By-product utilization Due to low yields associated with carrot juice production up to 50% of the raw material remains as pomace which is mainly disposed as feed or manure. However, this pomace contains large amounts of valuable compounds such as carotenoids, dietary fiber (Nocolle et al. 2003), uronic acids and neutral sugars (Stoll et al. 2003). Sometimes the pomace has posed environmental problems, therefore, new technologies are needed to decrease the problem (Alklint 2003). Fruit and vegetable processing units located in congested areas with limited space and inadequate water supply are finding it difficult to manage solid wastes with high BOD. These wastes pose increasing disposal and potential severe pollution problems and represent loss of valuable biomass and nutrients. During commercial juice processing, 30–50% of carrot remains as pomace (Bao and Chang 1994) and up to 50% of the carotene is lost with this pomace (Schieber et al. 2004). Total carotene content of pomace may be up to 2 g/kg dry matter depending on processing conditions (Singh et al. 2006). Carrot pomace contains 17 and 31–35% of the total α- and β-carotenes in the fresh unblanched and blanched carrots, respectively (Bao and Chang 1994). Tanska et al. (2007) have reported the microelements composition (mg/g) of dried pomace in 3.2±0.08 Na, 18.6±0.10 K, 1.8±0.04 p, 3.0±0.06 Ca, 1.1±0.05 Mg, 4.0±0.07 Cu, 10.8±0.12 Mn, 30.5±0.14 Fe and 29.4±0.16 Zn. Nawirska and Kwasniewska (2005) have reported the composition of dietary fiber constituents of carrot pomace (on dry weight basis) as pectin (3.88%), hemi-cellulose (12.3%), cellulose (51.6%) and lignin (32.1%). Hence, by-product of carrot after juice extraction represent promising sources of compounds with bioactive properties that could be explored in the development of food ingredients and dietary supplements (Moure et al. 2001; Schieber et al. 2001). Value addition to the waste helps to curtail the price of main product thus a direct benefit to the processors and consumers. Dehydration of carrot shreds with or without extracting juice during the main growing season could be one of the alternatives to make carrot products available throughout the year.

Efforts have been made to utilize carrot pomace in foods such as bread, cake, dressings, pickle, fortified wheat bread (Filipini 2001), preparation of high fiber biscuits (Kumari and Grewal 2007) and production of functional drinks (Oshawa et al. 1995; Schweiggert 2004). Consumer acceptance of such products still needs to be demonstrated especially sensory quality, which gets affected adversely (Stoll et al. 2003). Carrot pomace contains 4–5% protein, 8–9% reducing sugar, 5–6% minerals and 37–48% total dietary fiber (on dry weight basis) and therefore, carrot products are known to be a good source of dietary fiber (Bao and Chang 1994). Carrot pomace powder (Fig. 6) has been analyzed for proximate composition and total dietary fiber and incorporated at 10, 20, 30% levels into wheat flour to prepare high fiber sweet and sweet 'n' salty biscuits. Since, powder contained appreciable amount of ash and dietary fiber, it improved the mineral and fiber content of both types of biscuits (Kumari and Grewal 2007). Further, they have reported that carrot pomace on dry weight basis contains 2.5±0.15% moisture, 5.5±0.10% ash, 1.3±0.01% fat, 0.7±0.04% protein, 20.9±0.15% crude fiber, 55.8±1.67% total dietary fiber, 71.6±0.23% total carbohydrate and 301±0.09 kcal/100 g energy.

A study conducted on dehydration kinetics of carrot pomace revealed that optimal drying temperature was 65 °C on the basis of β-carotene and ascorbic acid retention (Upadhyay et al. 2008). Jagtap et al. (2000) have suggested that the carrot pomace containing relatively more total soluble solids, total and reducing sugars, non-reducing sugar, acidity and ascorbic acid can be utilized for the preparation of good quality toffees (Fig. 7). The chemical composition and yield of Asiatic and European carrot pomace toffees revealed that there was not much difference in 2 types of toffees however, the statistical analysis of the data for different parameters showed significant variation among them. When the influence of 5, 7.5 and 10% additions of carrot pomace in wheat bread was tested, it showed that the dried carrot pomace supplemented the bread with carotenoids, fiber, and mineral components. The best treatment from rheological and organoleptic point of view was 5% addition of carrot pomace (Tanska et al. 2007). Storage studies on dried carotenoid powder extracted from carrot waste revealed that isomerization of carotenoids occurs readily under high storage temperature (45 °C) or extended exposure to light (Chen and Tang 1998). Dried carrot pomace also contains 5.5% of mineral components including iron, zinc, potassium and manganese which can enrich wheat bread mineral composition since wheat is a poor source of microelements (100 g supplies only 1.4 mg of iron) (Ambroziak 1998).

Fig. 6 Preparation of carrot pomace powder

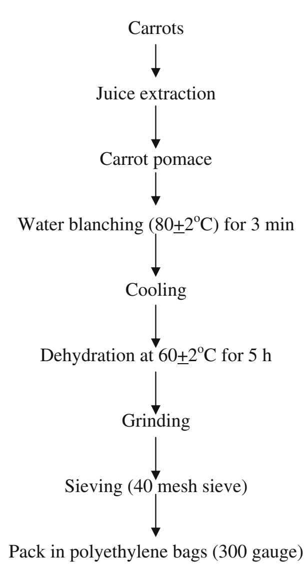
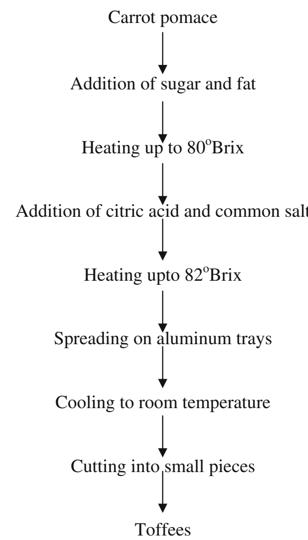


Fig. 7 Flow sheet for the preparation of carrot pomace toffees



Conclusion

Biochemically carrot is a rich source of β-carotene, fiber and many essential micronutrients and functional ingredients. The presence of high concentrations of carotenoids, especially β-carotene in carrot roots make them to inhibit cancers, free radical scavengers, anti-mutagenic and immuno-enhancers. Carrot being perishable and seasonal, it is not possible to readily make it available throughout the year. Dehydration of carrot during the main growing season is one of the important alternatives of preservation to further develop value added products throughout the year. Processing of carrots into products like canned slices, juice, concentrate, pickle, preserve, cake, and *halwa* are some of the methods to make this important vegetable available throughout the year. Carrot pomace containing about 50% of the carotenoids and important fibers could profitably be utilized to develop value added products. Further, supplementation of foods like bread, cake, and biscuits with dried pomace is other alternatives to curtail the price of main products like juice and concentrate resulting in direct benefit to the consumers. To exploit the antioxidant properties and dietary fibers of carrot pomace, there is a need to develop products with optimal phytochemicals content without sacrificing taste or convenience. It is therefore, visualized that the successful development of the products from fresh, semi-finished and dehydrated carrots may possibly meet the modern trend of consumers. At the same time, this will not only result in providing nutritious products at reasonable price to the consumers but also aid in efficient utilization of carrot pomace, which otherwise pose environmental problems.

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