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A review: Food, chemical composition and utilization of carrot (*Daucus carota* L.*)* pomace

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Abstract
Carrot is one of the vital root vegetables rich in bioactive compounds like carotenoids and dietary fibres with considerable levels of several other useful components having remarkable health-advancing properties. The utilization of carrot and its products is expanding relentlessly due to its recognition as an important source of natural antioxidants having anticancer activity. Carrot pomace having about 50% of β-carotene could beneficially be used for the supplementation of products like cake, bread, biscuits and preparation of several types of useful products. The present review highlights the nutritional composition, health advancing phytonutrients, functional properties, products development and by-products utilization of carrot and carrot pomace alongside their potential application.

Keywords: Carrot pomace, food, phytonutrients, antioxidants

Introduction
Carrot (*Daucus carota* L.) belongs to the family Apiaceae. South-western Asia especially Afghanistan is particularly to be the main centre of origin of this crop as the biggest morphological diversity in this crop has been found to occur in this region. Similarly the wild forms are also seen in Europe. Carrot is a prevalent cool season root vegetable cultivated in temperate countries mainly during spring and summer season while in tropical region during winter season. The most usually eaten part of a carrot is the taproot, inspite of the greens are eatable also.

India is the second largest producer of vegetables after China with a production of 169.478 million tonnes of vegetables from an area of 9.542 million hectares. Carrot growing states are Haryana, Tamil Nadu, Uttar Pradesh, Karnataka, Assam, Bihar, Telangana, Andhra Pradesh, Jammu & Kashmir and Madhya Pradesh with a total production of 1.338 million metric tonnes in 2015-16 (Anonymous, 2015) [1].

In India, the carrot is available in meager for most of the part of the year. At first, it grows a rosette of leaves while developing the augmented taproot. Suitable time for sowing of carrot seed is varied from early September to early November and it takes about 80-90 days from sowing to root formation. They develop best in full sun however endure some shade. The ideal temperature is 16 to 21°C (Anonymous, 2017) [2]. The roots achieve marketable stage when their distance across is 1/2 to 3/4 inch at the upper to end. Reaping of carrot root is done from mid-December to end of February.

Important Varieties
Important varieties of carrot which are cultivated in India are Pusa Kesar, Pusa Meghali, Early Nantes, Selection 223, Nantes Half Long, etc. (NHB, 2010). The important characters of different varieties of carrot are given in Table 1.

Table 1: Important characteristic of different varieties of carrot

Variety	Developed by	Characteristics
Pusa Kesar	IARI, New Delhi.	It has red-hued roots and self-hued core. It can endure higher temperatures. Appropriate for sowing from August to early October. Product develops in 90-110 days with average yield 30 t/ha.
Pusa Meghali	IARI, New Delhi	It has orange tissue, self-shaded core and short top. Appropriate for sowing from August to September. Average yield is 25-30 t/ha.
Selection 223	PAU, Ludhiana.	Roots are orange in shading with light orange tissue.
No. 29	PAU, Ludhiana.	It has roots are long tapering and light red in colour.
Nantes Half Long	-	It has tube shaped short roots, orange-red with self-hued core crop
Early Nantes	-	It is an European cultivar. Relatively tube shaped roots ending unexpectedly in little thin tail. Phenomenal quality however has a feeble weak top which makes pulling troublesome. Because of thin skin and fine surface, it can be put away for a constrained period. Crop matures within 90-100 days.
Chantenay	-	An excellent cultivar for canning and storage. Roots are alluring orange smooth, thick at the shoulders with progressive decreasing. It is juicier with less fibre content.
Imperator	-	It is a mid-season to late-maturing cultivar with white profound orange roots. Roots are 15-17.5 cm long and 2.4-4.5 cm in distance across with decreasing to marginally adjusted end.
Zeno	-	Popular in Nilgiri hills, high yielding and famous.

Classification for Kingdom Plantae Down to Species Daucus carota L.

- Kingdom Plantae – Plants
- Subkingdom Tracheobionta – Vascular plants
- Superdivision Spermatophyta – Seed plants
- Division Magnoliophyta – Flowering plants
- Class Magnoliopsida – Dicotyledons
- Subclass Rosidae
- Order Apiales
- Family Apiaceae – Carrot family
- Genus Daucus L. – wild carrot
- Species Daucus carota L. – Queen Anne's lace
- (Source: Anonymous 2018) [3]

Carrot Plant Morphology

Leaf

Carrot leaves are compound pinnate double two or three; children are lancet-shaped leaves (lines). Each plant has a size 5-7 petiole rather long. Petiole firm and thick with a smooth surface, while the leaf cutting edge limp and thin.

Rod

Carrot plant stems are so short that barely visible, round rods, somewhat hard and small diameter (approximately 1-1.5 cm). In general, dark green stems.

Roots

Plant carrots have stringy root framework and riding. In the taproot growth will change the shape and function of the capacity of nourishment holds. Root frame will transform into a major lengthened and round, until the point when it achieves a distance across of 6 cm and a length of up to 30 cm, contingent upon assortments. Taproot that has changed frame and capacity is regularly called or known as "Carrot Root".

Interest

Flowers develop carrot plants toward the finish of the crop, twofold umbrella - molded, and white or pale pink. Blossoms have short stalks and thick. Bloom petals lie in a similar plane who had encountered carrot blossom fertilization will create products of the soil are little and fuzzy.

Bulbs

Carrot is a tuber vegetable crop season, molded bush that can be developed consistently, both in the wet and dry seasons. The storage compartment is short and stable roots whose capacity turns round and prolonged. Shading ruddy yellow globules have a high carotene. Carrots Bulbs additionally contain B vitamins, vitamin C and minerals.

Chemical properties of carrot

Carrot root is considered as one of the most delicious and luscious root and is highly nutritive. The total soluble solids content in chips/slice varies from 12° Brix (Machewad *et al*., 2003) [4]. Orange coloured carrots are rich in carotene; a precursor of vitamin A. It has good nutritional value with 42 kcal of energy, 1.1g protein, 1100 IU vitamin A, 8 mg ascorbic acid, 0.06mg thiamine, Ca 37 mg, P 36 mg and iron 0.7 mg per 100 g of fresh sample (Thamburaj and Singh, 2005) [5]. Carrots are a good source of carbohydrates and minerals like Ca, P, Fe and Mg. (Gopalan *et al*., 1991) [6] 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) [7] 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) [8]. (Kaur *et al*., 1976) [9] 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. The free sugars identified are sucrose, glucose, xylose and fructose (Kalra *et al*., 1987) [10]. The crude fiber in carrot roots consist of 71.7, 13.0 and 15.2% cellulose, hemicellulose and lignin, respectively (Kochar and Sharma, 1992) [11]. The taste of carrots is mainly due to the presence of glutamic acid and the buffering action of free amino acids. Thiamin, riboflavin, niacin, folic acid and vitamin C are present in appreciable amounts in carrot roots (Howard *et al*., 1962; Bose and Som 1986) [8, 12].

Phytonutrients

Plant components, essentially optional metabolites that have health promoting properties are called phytonutrients. The significance 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) [13-15]. In vitro contemplates showed phytonutrients, for example, carotenoids and phenolics may assume a noteworthy part, notwithstanding vitamin in shielding natural frameworks from the impacts of oxidative pressure (Kalt 2005) [16]. Carrot is a significant source of phytonutrients including phenolics (Babic *et al.*, 1993) [17], polyacetylenes (Hansen *et al.*, 2003; Kidmose *et al.*, 2004) [18, 19] and carotenoids (Block 1994) [20]. Carrot is rich in β-carotene, ascorbic acid and tocopherol and is classified as vitaminized food (Hashimoto and Nagayama 2004) [21]. Because of obvious level of wide range of mixes exhibit, carrots are considered as a practical nourishment with noteworthy wellbeing advancing properties (Hager and Howard 2006) [22].

Carotenoids

The significance of carotenoids in sustenance goes beyond as natural pigments and biological functions and actions have progressively been ascribed to these pigments. Carotenoids are present intracellularly and their activities include in the control of quality articulation or impact cell capacities like hindrance of monocyte grip and platelet actuation (Rock 1997) [23]. These biological effects are independent of the pro-vitamin an 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) [24, 25]. 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) [26].

Phenolics

Phenolics or polyphenols have received remarkable 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 dangerous to our body and foods systems (Nagai *et al.*, 2003) [27]. Although, phenolic compounds do not have any known nutritional function, they may be significant to human health because of their antioxidant potency (Hollman *et al.*, 1996) [28].

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. Lineback (1999) [29] has studied that the carrot cell wall contain 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 rich in dietary fibers (Bao and Chang 1994) [30] and these fibers have an important role in human health (Anderson *et al.*, 1994) [31] 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) [31-33].

Medicinal benefits of carrot

Carrot is used for many medicinal properties; it is said to cleanse the intestines and as diuretic, remineralizing, antidiarrheal, an overall tonic and antianemic. Carrot is enrich with alkaline elements which purify and revitalize the blood. It has significant antioxidant constituents for the maintenance of health and protection from coronary heart disease. It has anti-cancer property which raised considerable interest of the scientists, food manufacturers and consumers as the trend of the future which is moving toward functional and theraptical food with specific health effects (Velioglu *et al.*, 1998; Kahkonen *et al.*, 1999; Robards *et al.*, 1999) [13-15]. Carrot is a important source of phytonutrients including phenolics (Babic *et al.*, 1993) [17], polyacetylenes (Hansen *et al.*, 2003; Kidmose *et al.*, 2004) [18, 19] and carotenoids (Block, 1994) [20]. Carrot is rich in β-carotene, ascorbic acid and tocopherol and is classified as vitaminized food (Hashimoto and Nagayama, 2004) [21]. Because of appreciable level of variety of different compounds present, carrot is considered as a functional food with significant health promoting properties (Hager and Howard, 2006) [22].

Carrot is the power house of nutrients. They are quite helpful in:

- Boosting immunity (especially among older people)
- Reducing photosensitivity (beta-carotene protects the skin from sun damage)
- Improving symptoms of HIV
- Easing alcohol withdrawal symptoms
- Helping to heal minor wounds and injuries
- Reducing the risk of heart disease
- Reducing the risk of high blood pressure
- Cleansing the liver, and when consumed regularly, can help the liver excrete fats and bile
- Fighting bronchitis
- Fighting infection (vitamin A keeps cell membranes healthy, making them stronger against disease-causing microorganisms)
- Improving muscle, flesh, and skin health
- Helping fight aneamia
- Reducing acne
- Improving eye health, etc

Carrot Pomace

Fruit and vegetable processing industries has grown tremendously around the globe as a response to reduce post-harvest losses and generate income. However, processed food industry has accounted 25% losses and wastages in the form of organic waste such as peel, stem, core, seeds and pomace from juice extraction. By-product obtained from fruit-processing plants offers untapped potential of producing low cost natural bio-components having food applications. Hence, there is need to give attention to utilize tons of pomace produced each year to address environmental issues and generate new income source. Utilization of pomace in food applications is important from nutritional point of view as

they possess good amount of tocopherols, phytosterols, carotenoids and antioxidant activity.

As per the statistics of Ministry of Food Processing Industry, about 76% of the total fruits and vegetable production is consumed as fresh and approximately 20 to 22% goes as wastage. Out of the total production, processing accounts for only 2% for vegetables and 4% for fruits (MOFPI 2015). Processed fruit and vegetable industry has accounted 25% losses and wastages after processing of fruits and vegetables that includes 10% during distribution and 7% during consumption. This results in localized production of large tonnages of waste co-products. The waste management is often achieved by landfill, land spreading or selling as animal feed or for its production.

The major waste produced includes the organic waste such as peel, stem, core, seeds and pomace. This remaining matter can be converted using suitable technology to produce multi-functional food ingredients or can be used as raw material in the secondary processes. Morever, it can be utilized in operating supplies or for producing new products. These by-products can be used as a valuable source of biological food additives that can be significant alternative toward alleviation of food safety issues. These can also be used for development of food additives or supplements with high nutritional value that are economically feasible. Hussein *et al.*, (2015) [34] studied the possibility of utilizing fruit and vegetables by-products to produce high dietary fibre jam. The author concluded that these by-products were excellent source of low priced functional food components and the jam made by using carrot peel, apple pomace, banana peels and mandarin peels was rich in dietary fibre, vitamin C, enhanced minerals, total flavonoids and antioxidant activity. This transformation of by-products into a high value product makes it possible for food companies to reduce their cost and generate benefits, thereby, improving their competitiveness. In this context, the main motive of this review article is to enhance the potential of fruit and vegetable processing waste especially with respect to pomace. Basically, pomace is defined as the solid remains of fruit and vegetable after pressing for juice or oil.

Utilization of carrot pomace

Due to less yields incorporated with carrot juice production up to 50% of the raw material remains as pomace which is generally disposed as feed or manure. However, this pomace contains big amounts of valuable compounds such as carotenoids, dietary fiber (Nocolle *et al.*, 2003) [35], uronic acids and neutral sugars (Stoll *et al.*, 2003) [36]. Sometimes the pomace has posed environmental problems; therefore, new advance technologies are needed to solve the problem (Alklint 2003) [37]. Fruit and vegetable processing units located in congested areas with limited space and inadequate water supply are finding it tough to manage solid wastes with high BOD. These wastes pose progressively 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) [30] and up to 50% of the carotene is lost with this pomace (Schieber *et al.*, 2004) [38]. Total carotene content of pomace may be upto 2 g/kg dry matter depending on processing conditions (Singh *et al.*, 2006) [39]. 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) [30]. Tanska *et al.*, (2007) [40] have studied the micro-elements 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)[41] have studied 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) [42, 43]. Value addition to the waste helps to curtail the price of main product thus a direct profit 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, fortified wheat bread, pickle, cake, dressings (Filipini 2001) [44], preparation of high fiber biscuits (Kumari and Grewal 2007) [45] and production of functional drinks (Oshawa *et al.*, 1995; Schweiggert 2004) [46, 47]. Consumer acceptance of such products still needs to be demonstrated especially sensory quality, which gets affected highly (Stoll *et al.*, 2003) [36]. 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) [30]. Carrot pomace powder 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 salty biscuits. Since, powder contained good amount of ash and dietary fiber, it improved the mineral and fiber content of both types of biscuits (Kumari and Grewal 2007) [45]. Further, they have studied that carrot pomace on dry weight basis contains $2.5 \pm 0.15\%$ moisture, $5.5 \pm 0.10\%$ ash, $1.3 \pm 0.01\%$ fat, $0.7 \pm 0.04\%$ protein, $20.9 \pm 0.15\%$ crude fiber, $55.8 \pm 1.67\%$ total dietary fiber, $71.6 \pm 0.23\%$ total carbohydrate and 301 ± 0.09 kcal/100 g energy.

Jagtap *et al.* (2000) [49] 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. 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. 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) [51].

Conclusion

Carrot as well as carrot pomace having good quality of reducing the risk of heart disease, reducing the risk of high blood pressure, cleansing the liver, and when consumed in regular basis, can help the liver excrete fats and bile and fighting bronchitis. Carrot has been found to have significant bioactive compounds. Carrot pomace powder has been used to develop various types of bakery products and extruded product. Based on these various health usefulness as discussed in review, based on various past reported scientific findings, carrot can be recommended and must be taken as a part of our daily diet as its liberal utilization is safe and various health benefits can be drawn from this natural herb. The above-mentioned studies on carrot pomace suggest that the functional, nutritional and therapeutic characteristics of

carrot can be exploited further in the development of healthy products.

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