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CHEMICAL CHARACTERIZATION, NUTRITIONAL BENEFITS AND SOME PROCESSED PRODUCTS FROM CARROT (*Daucus carota* L.)

SUMMARY

Carrot (*Daucus carota* L.) is a famous horticultural crop eaten all over the planet and can be used raw, cooked or processed. It is well known by its high β-carotene content but its' root also contains carotenoids, phenolic compounds, vitamin C and polyacetylenes. This review article discusses both: carrots chemical composition and nutritional value, and some of the processed carrots products such as: beverages (juice, yoghurt, smoothies and milk), jam and jelly, carrots chips (dehydrated non-fried carrot chips, deep-fried carrot chips and whole grain carrot chips), carrots edible seed oil and carrots essential seed oil. However, the main purpose of this article is to inform the reader about afore mentioned carrots products and the latest technology achievements in their production, as well as to highlight carrot as a functional food rich in nutrients.

Keywords: *Daucus carota* L., carrot, β-carotene, carrots beverages, carrots jam and jelly, carrots chips, carrots edible seed oil, carrots essential seed oil.

List of abbreviations:
DPPH - 2,2-diphenyl-1-picrylhydrazyl assay
EPS - exopolisaccharides
G-C - gas chromatograpy
GC-MS - gas chromatography-mass spectrometry
HTLT - high temperature-long time
HTST - high temperature-short time
MTLT - mild temperature-long time
MTST - mild temperature-short time
TBRS - thiobarbituric acid reactive substances assay

INTRODUCTION

Daucus carota L. (carrot) belongs to *Apiaceae* family and is the most significant plant of that family (Silva Dias, 2014). It is considered as one of the 10 most appreciated crops from economic point of view, and broadly used radix

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in peoples' diet (Ergun and Süslüoğlu, 2018). Also, it has been rated sixth in per person utilization out of 22 popular vegetables (Zhang and Hamauzu, 2004). Recently, utilization of carrot and its processed products has expanded regularly because of their admission as an meaningful source of antioxidants, as well as β-carotene (which is a precursor of vitamin A) activity against cancer (Sharma et al., 2012). Carrots are the main source of provitamin A and they bring 17% of its intake (Zhang and Hamauzu, 2004). A good processing method is crucial for producing products which are not only greatly liked by customers but also a satisfying source of phytonutrients like β-carotene in order to boost carrot consummation (Sulaeman et al., 2001).

This review aims at highlighting raw carrot chemical composition and nutritional value but as its' major has some of the processed carrot products such as beverages, jam and jelly, carrots chips, carrots edible seed oil and carrots essential seed oil. This review provides latest research in the field of afore mentioned processed carrot products.

1.Survey methodology

The literature for this review paper was retrieved from Google Scholar by using following key words: carrot (*Daucus carota* L.); nutritional value and chemical composition of raw carrots; nutritional value and chemical composition of carrot seeds; "provitamin A activity" of carrots; occurrence of phenolics or phenols or phenolic acids, carotenoids, polyacetylenes and ascorbic acid or vitamin C in carrots; carrots processing; main components, functions and nutritive value of jam and jelly, deep-fried chips, dehydrated slices, juice, milk, yogurt, smoothie, edible seed oil and essential oil from carrots.

More than 70 articles including original research papers, review papers and books were downloaded, and all of the articles were relevant to the topic and up-to-date so they were all selected for writing this review article.

2.*Daucus carota* L.

a. Description

According to Shakheel et al. (2017) carrot can be characterized as a biennial crop that belongs to the family *Apiaceae*. It is an erect perennial vegetable (Negi and Roy, 2000), tall booming spiny-fruited herb (Özcan and Chalchat, 2007) with height of 0.3 to 0.6 m; hairy and with a strong stem (Kataria et al., 2016).

Firstly, a rosette of leaves is formed (in the spring and summer) along with the extended taproot which stores large volume of sugars that will be used by the plant in the second year to form flowers (Shakheel et al., 2017). Negi & Roy (2000) also confirms that flower and seeds are produced in the second year. There are some varieties, called fast-growing, that mature in a period of three months (90 days) after sowing, however others called slower-maturing varieties are collected four months later (120 days) (Shakheel et al., 2017).

Tap root is bloated, thick, usually orange-red, in conical shape or thin and light colored even tough cylindrical and round ones are also available (Kataria et al., 2016). It consists of cortex, which is pulpy, and central core. Most of the taproot consists of a pulpy outer cortex and an inner core. Finest-quality carrots have a smaller amount of core compared to cortex. Some sorts have tiny in size and deeply pigmented core, but a totally xylem-free carrot is not possible; the taproot can seem to lack a core when the color of the cortex and core are of similar intensity. The width of root can range from 1cm to 10cm and its length from 5 to 50cm, even though most of them are from 10 to 25cm long (Shakheel et al., 2017).

Stem is striated, brushy-haired or condensed and with not distinct internodes (Kataria et al., 2016). It is situated just above the ground. When the stem of the plant elongates, the very tops becoming thinner and grows pointed, it lengthens upward, and becomes a very branched inflorescence. The stems usually grow to 60-200cm (Shakheel et al., 2017).The leaves are tri-pinnate, finely cleft, pedicel, netlike and of overall triangular shape (Kataria et al. 2016). The first real leaf develops from 10 to 15 days after germination. Following leaves, which are formed from the stem nodes, are intermittent and compounds, and disposed in a spiral. While the plant grows, the bases of the seed leaves are suppressed (Shakheel et al., 2017).

The inflorescence is a complex umbel, and every umbel consists of few umbellets. A big primary umbel sometimes has around 50 umbellets, and every umbellet may contain up to 50 small, white flowers. They are frequently with a light green or yellow tint, organized in a flat umbrella-like head or umbel, build from five petals, five stamens and calyx. The carrots fruits are pressed from the sides and oval, 2-4mm with short styles and hooked spines (Kataria et al. 2016).

b. Anathomy

After appearance the young carrot plant shows a bright difference between the taproot and the hypocotyl. The taproot is firstly thick and do not carry side roots. At the end of hypocotyl there is cotyledonary node. Here the physical foundation of the cotyledons evenly comes together with the hypocotyl (Kjellenberg, 2007). The depository root is mostly composed of phloem and xylem along with cambium area evenly joining together in a cylinder. The form of a depository root varies; it can be round, conical or even cylindrical. When it comes to pigment combination there are purple, red, yellow, white and orange carrots. Configuration and color are affected by genetic factors as well as environmental circumstances but also varies between different plant development stages (Kjellenberg, 2007).

c. Distribution

Wild carrot is native to Western or the near East Asia and it can be found in the Mediterranean area, Southwest Asia, Tropical Africa, Australia and North and South America. It is seen as a crucial weed in Hungary, Greece, Afghanistan, and Poland, a dominant weed in Puerto Rico, Jordan, Mauritius, Sweden, and Tunisia, an ordinary weed in Canada, Austria, Egypt, Germany, England, Iran, Iraq, USA, and West Polynesia. Carrot takes up residence in a rid open lands and uncultivated places and it can be found at low altitudes throughout the northern United States from Vermont to Virginia west to Washington and California; and more up to north into Canada (Kataria et al., 2016).

Cultivated carrot is the one of the main vegetable crops in global. The tamed breeds are detached into two groups: the Eastern or Asian carrots (var. *atrorubens*), with primarily purple and yellow roots color; and the Western carrots (var. *sativus*) with mainly orange roots color.

It is believed that carrot was domesticated in Afghanistan at first, and they were spread over Europe, Asia and the Mediterranean area (Al-Snafi, 2017).

d.Origins

Central Asia (Vavilov, 1992) or Asia Minor (Banga, 1957) is thought to be the origin of cultivated carrot used as root storage has generally been accepted to be either. The results obtained from Iorizzo et al. (2013) strongly separate cultivated carrot from wild carrot and strongly place wild carrots from Central Asia as the closest genetic relatives of domesticated carrot, supporting Vavilov's (1992) hypothesis. To the Iorizzo et al. (2013) research, the origin(s) of carrot domestication has not been studied, and only a small number of studies have used molecular markers to examine carrot genetic diversity. Present-day carrots are strongly disparate from ancestral ones with decreased bitterness, raised sweetness, decreased endocarp fraction (Ergun and Süslüoğlu, 2018). First carrots were purple and yellow, firstly characterized in the 10th century in Iran and northern Arabia (Simon, 2000). After being spread carrots became known on the Middle East, North Africa, Europe, and China by the middle of 15th century. In northern Europe they loved yellow carrots before growth of orange ones. White carrots were famous in Europe and red carrots are believed for being introduced in China about this time (Arscott and Tanumihardjo 2010). First hypotheses for explaining the origin of orange carrots proposed Vilmorin (1859). He deduced that orange carrots were elected in Europe straight derived from wild carrots. Small (1978) and Thellung (1927) taught that they had an ancestor in Mediterranean and that they were result of hybridization with *D. carota* subsp.*maximus.* Banga (1957) made an assumption that they were elected from cultivated yellow carrots and Heywood (1983) made a conclusion that they were hybrids between cultivated European carrots and wild ones. We should be aware of the fact that none of these hypotheses was not established on genetic analyses, instead, it was based on taxonomic analyses, historical archive, and geographical distribution of wild carrot and cultivated orange carrot (Iorizzo et al., 2013). *Y* and *y2* are two recessive genes which majorly regulate accumulation of yellow and orange carotenoids in the carrots root (Just et al., 2009). Genetic evidence suggests that two recessive genes, *y* and *y2*, play a major role in the accumulation of yellow and orange carotenoids in the root of carrot (Just et al., 2009). This information, together with the study of Iorizzo et al. (2013), supports Banga's (1957) hypothesis which states that orange root color was selected out of yellow, domesticated carrots.

e.World production

Carrot (*Daucus carota* L.) represents the most valuable root vegetable and the leading vegetable of the family *Apiaceae* (*Umbelliferae*) (Simon et al., 2008). It was firstly used as a medical plant in middle Asia and after that it became an important world crop (Stolarczyk and Janick, 2011). Although carrots are not a predominant food in any part of the world, because of the low nutritional value, they are deliberated as an essential vegetable in lot of countries (Arscott and Tanumihardjo 2010). The domesticated carrot (*Daucus carota sativus*) is cultivated around the world (Nguyen and Nguyen, 2015) Nowadays, production of carrots is: 61% from Asia, 24%Europe, 9.7% the Americas and 4% Africa (Nguyen and Nguyen, 2015). The 50% of world carrot production belongs to China, Russia, and the United States which are the 3 biggest producers of carrot (Arscott and Tanumihardjo, 2010). China is the country with the biggest carrot production affirmed by the FAO 2008 (Sharma et al., 2012). Carrots can be produced in temperate region. Production of carrots in tropical regions is more restricted; still, subtropical region in South America are suitable for this (Arscott and Tanumihardjo, 2010). It has been stated that 30–40 tons of car¬rots/ha is noted as a good yield, even though strong farmers can reach a goal of 60 tons or more. Carrot production has 7.85 MT, in 1990 it was 13.7 MT, in 2000 - 21.4 MT, and reached 35.658 MT in 2011 (FAOSTAT 2013) (Nguyen and Nguyen, 2015). This increase is a consequence of development of product areas, advanced agricultural practice, agriculture mechanization, and development of hybrid breeding methods (Bradeen and Simon, 2007).

4. Chemical composition and nutritive values of raw carrot root

4.1 Chemical composition

a.Core nutrients

Carrot root consists of almost 88% water, 1% protein, 7% carbohydrate, 0.2% fat, and 3% fiber (USDA 2008) (Arscott and Tanumihardjo, 2010).

Carrots are an excellent source of carbohydrates and minerals. Among carbohydrates there are most of simple sugars (Arscott and Tanumihardjo, 2010).: sucrose, glucose, xylose and fructose (Kalra et al., 1987) with a insignificant amount of starch (USDA 2008) (Arscott and Tanumihardjo 2010). In some plant species most important macroelements are found to be K, Ca and Mg (Bošković et al. 2018) and in carrots we have: Ca, P, Fe and Mg (Surbhi et al., 2018). Carrots are also rich in fiber including cellulose (50%), hemicellulose (92%) and lignin (4%) (Marlett, 1992). Composition of carrot root is given in a Table 1. Composition of carrot root (According to: Hag and Prasad, 2015).

Table 1. Composition of carrot root (According to: Hag & Prasad, 2015).

Parameter	**Component**	**Composition**	**Availability**	**References**
Proximate analysis	Moisture	86-88.8	gm/100gm	Golpan et al. (1991) Holland et al. (1991) Thomas (2008)
	Carbohydrate	6-10.6		
	Protein	0.7-1.0		
	Fat	0.2-0.5		
	Fiber	1.2-2.4		

b.Other phytochemicals

Carotenoids are one of the dominant pigments in carrots root. There are 6 carotenes (*α*-, *β*-, *γ* -, and *ζ* -carotenes, *β*-zeacarotene, and lycopene) that can be distinct and measured in typical and dark orange carrots. Provitamin A carotenes are dominant (*α*-carotene (13-40%) and *β*-carotene (45-80%)) (Arscott and Tanumihardjo, 2010).

Polyphenols are studied because of the fact they are the most important compounds for the antioxidant properties of plant raw materials (Pejatović et al. 2017). Zhang and Hamauzu (2004) found that carrot contain primarily: hydroxycinnamic acids and derivatives such as chlorogenic acid, caffeic acid, 3'-caffeoylquinic acid, 4'p-coumaroylquinic acid, 3',4'-dicaffeoylquinic acid, 3',5'-dicaffeoylquinic acid and few unidentified hydroxycinnamic derivatives. These are all phenolic compounds. Although the total phenolics values in plants extracts depend a lot on the extraction solvent (Faiku et al. 2019) and are found to be highest in ethanol extracts (Bošković et al. 2018) in particular carrot tissues they decrease in this manner: peel > phloem > xylem (Zhang and Hamauzu, 2004). Purple carrots contain 9 times more phenolic compounds than carrots of different colors (Al-Snafi, 2017).

The second group of polyphenols are flavonoids. Similarly as total phenolics the amount of total flavonoids in Singh et al. 2018. was found maximum in black and then in rainbow carrots, significant amount was found in red and orange carrots and minimum in yellow carrots. It is important to point out that the average phenolic content is higher (> two-folds) than the total flavonoids in different sorts of carrots. The most important flavonoids in plant kingdom are flavonols and flavones. When it comes to carrots, anthocyanins give the purple and black colour of roots and because of that there are higher values of phenolics and flavonoids in the roots of black and rainbow carrot types (Singh et al. 2018).

C17-polyacetylenes are important because of cytotoxic effect on cancer cells. Plants of the *Apiaceae* familiy contain aliphatic C17-polyacetylenes of the falcarinol type. Falcarinol, falcarindiol, and falcarindiol-3-acetate are essential polyacetylenes found in carrot roots (Ahmad et al., 2017).

Together with these bioactive compounds, carrots consist of different and important amount of Vitamin C, E, and K, folate and choline (Ergun and Süslüoğlu, 2018). They have appreciable quantity of vitamin C (5.9 mg 100 g^{-1} fw). This is higher in comparison with grapes, nectarines, pears, and plums etc. (Char, 2018).

4.2 Nutritive value

Carrots root is frequently used part of the plant in human diet, even though young leaves are used seldom in China and in Japan (Arscott and Tanumihardjo , 2010).It is very nutritive because it contains β-carotene as well as vitamins B1, B2, B6, and B12. It is taught to be one of the most pleasant and delicious roots (Yi et al., 2018). Beside B vitamins carrots have appreciable amount of thiamin, riboflavin, and niacin (Arscott and Tanumihardjo, 2010). In order to afford enough quantity of vitamin C and A one should consume 73 kg/capita/year of vegetables (Ali and Abedullah, 2002) and at least 146 kg/year (5 portions per day) for the best health. Carrot can not provide an important amount of calories to the human diet (Arscott and Tanumihardjo, 2010). Even though it has fine nutritional value = 42 kcal of energy, 1.1g protein, 1100 IU vitamin A, 8 mg ascorbic acid, 0.06 mg thiamine, Ca 37 mg, P 36 mg and iron 0.7 mg per 100 g of fresh specimen (Surbhi et al., 2018). Surbhi et al. (2018) state that 100g from 4 carrot carrot cultivars has 10% carbohydrates (among them soluble carbohydrates ranging from 6.6 - 7.7 g and protein (0.8 - 1.1 g).

5.Processed products from carrots

5.1 Juice and beverages

We ingest fruits and vegetables sometimes through juices, blends, smoothies, fermented and fortified beverages, which is a contribution to healthy aliment as well as a life habits (Petruzzi et al., 2017).

Juice

Juices have become a part of everyday meals for people all around the globe. They are tasty source of vitamins, minerals and fibers (Janve et al., 2014). The juice from carrots is regularly consumed like a vigorous drink (Singh and Chandra, 2012). It is rather used as a good source of β-carotene. The alpha-tocopherol-beta-carotene drinks (ATBC-drinks) are made from this juice and they have exceptional physical and chemical stability (Reiter et al., 2003). Carrot juice has notably high content of β-carotene, a source of vitamin A and it is rich in B complex vitamins and a lot of minerals including calcium, copper, magnesium, potassium, phosphorus, and iron. It has an especially sweet flavor. Difference to other juices is that it is opaque (Singh and Chandra, 2012). This juice is extracted by different methods like centrifugal basket, centrifugal pulp ejecting, twin gear, two step triturator and hydraulic press, and mastication juice extractors (Hag and Prasad, 2015). The common extractors culminate in poor juice yield because of the very solid root structure. Yield could be raised by enzymes or heat treatment but which can lead to the decrease in nutritive value (Hag and Prasad, 2015). There are few technologies (mash heating, depolymerizing enzymes, or decant¬ing centrifuges) which can lead to improved yield (Nguyen and Nguyen, 2015). Just produced carrot juice contains 84% water, 7% carbohydrate, 1% protein and 7% dietary fibers (Shakeel et al. 2013). More detailed chemical composition of fresh carrot juice is given in the Table 2.

Table 2. Chemical compositon of fresh carrot juice (According to: Salwa et al., 2004).

Chemical composition of fresh carrot juice	
Total solids % (F.Wt.)	7.15
Titratable acidity as citric acid % (T.A and D.M)	2.58
Total carotenoids (mg/100g)	12.00
pH	5.85
Moisture % (F.Wt.)	92.85
Total soluble solids % (T.S.S &F.Wt)	6.45
Total sugars % (D.M)	36.80
Riboflavin mg/g	0.62

*F.Wt.: Fresh weight. **D.M: Dry Matter.

It is found that thermal procedure before juice extraction is a great act in the manufacture cloud stable juices (Reiter et al., 2003). Conventional thermal processing, before carrot juice production as well as carrot juice blends, summarized by Petruzzi et al., (2017) was: 1) high temperature-long time (HTLT), 2) high temperature-short time (HTST), 3) mild temperature-long time (MTLT) and 4) mild temperature-short time (MTST) processing.

1) HTLT can be seen in several different studies such as Dereli et al. (2015) and Sinchaipanit et al. (2013) for pure carrot juice, and Yadav (2015) for carrot juice blended nectar. Dereli et al. (2015) found that processing carrots for 10min at 90°C increase total phenolics and hydroxycinnamic acid contents and, in order to get reduced-calorie carrot juice, Sinchaipanit et al. (2013) treated carrots for 1min at 80°C and concluded that Salmonella sp. or Staphyloccoccus aureus were below the detection limit and that there was the reduction of yeasts, molds, and total coliforms. Pretreatment of carrots in Yadav (2015) before producing carrot-grape and carrot-pomegranate blended nectar gave next results: the total sugars content was significantly higher at 80°C for 5min and also, there was decrease of vitamin A when increased processing temperature and heating time.

2) HTST (temperature equal or above 80 °C and holding times equal or less than 30 s), Petruzzi et al. (2017) is reported by Chen et al. (2012); Sinchaipanit et al. (2013) and Barba et al. (2010). Chen et al. (2012) concluded that there was higher viscosity and low stability of particles dispersion during the refrigerated storage. From Sinchaipanit et al. (2013) it is obvious that, after HTST, there was low β-carotene content in reduced-calorie carrot juice, while Barba et al. (2010) detected decrease of ascorbic acid in blended beverage.

3) MTLT (temperature <80°C and holding times >30 s), Petruzzi et al. (2017) was evaluated by Sinchaipanit et al. (2013); Aguiló-Aguayo et al. (2014); Profir & Vizireanu (2013) and Dima et al. (2015). Huge holding of β-carotene capacity and production of a non satisfactory cooked flavor is expected when pretreating carrots for 30 min at 65°C (Sinchaipanit et al., 2013). Juices processed at low temperatures of 20°C demonstrated an improvement on both falcarinol and falcarindiol-3-acetate contents with increasing the processing time up to 10 min in comparison with untreated juices. In comparison, longer processing times of 30 and 60 min did not affect the polyacetylene levels of the samples (Aguiló-Aguayo et al., 2014). Huge deficits of vitamin C, along with low increase of acidity throughout the consequent storage for 2 weeks at 4°C was found while processing carrot, celery and beetroot on MTLT (Profir and Vizireanu, 2013). Further, according to Dima et al., (2015) MTLT (70 °C/10 min) before creating carrot juice blend had negative influence on flavor and flavonoids during the refrigerated storage for 14 days.

4) MTST heat processing uses temperatures <80°C and holding times equal or less than 30s. Still, MTST treatment can affect the physicochemical, olfactory and functional properties of beverages, especially color and flavor in a carrot/orange juice blend (Caminiti et al., 2011). There are some new thermal technologies next to the common thermal processing that have been studied as alternative methods to heat treatment (Mercali et al., 2015).

An encouraging method is microwave heating (MWH) because of its advantages like: the decreased processing time, great energy efficiency, a good process menagement, and space saving (Salazar-González et al., 2014). As it can be seen in Rayman and Baysal (2011) carrot pretreatment at 540-900W during 4min at the temperature lower than 90°C results in total inactivation of PME.

One other alternate procedure to heat treatment is ohmic heating (OH). Jakób et al. (2010) concluded that there is destabilization of the labile isozyme fraction of POD after carrot tretement 6 to 1500 min at temperature between 58 and 78°C. In the study of Profir and Vizirean (2013) carrot, celery and beetroot juice blend was investigated after OH of raw vegetables at 17.5V/cm^3 to 4 min at 70°C. They noticed low loss of ascorbic acid throughout the refrigerated storage for 2 weeks.

Finally, Dima et al. (2015), who also used OH, found no negative influence on flavor of carrot and other vegetables juice blend. Just produced and thermally untreated carrots juice should be used up in a period of 1-2 days, because it can be a good source of nourishment for microorganisms (Hag and

Prasad, 2015). Carrot juice is thought to be a fine growth medium for *Lactobacillus* strains. In carrots juice *L. rhamnosus* and *L. bulgaricus* demonstrated meaningful growth and reached about 109 cfu ml^{-1} at the end of fermentation. Furthermore, these 2 Lactobacillus strains showed important survival at low pH (43.5) during 30 days of storage (Nazzaro et al., 2008).

Yoghurt

Yoghurt has high nutritive and advantageous effects on people and it is one of the favorite fermented milk which is produced worldwide. Because of the addition of fruit and vegetable flavored yoghurt production and consumption of yogurt has increased during the last quarter of XX century. Addition of fruits and vegetables to the yogurt makes it a good prebiotic, although these agents also act as flavouring and coloring agents as well as antioxidants (El Samh et al., 2013). Presently researchers are working on usage of carrot juice in making yoghurt. The goal is to offer assortment and competition in the market (Schieber et al., 2002; Simova et al., 2004). When blended yogurt and carrots juice give very nutritive food (Ikken et al., 1998; Raum, 2003). This kind of yogurt can boost consumer's satisfaction because of the pleasant characteristics, viable lactic acid bacteria and β-carotene advancement (Amany et al., 2012). On the Figure 1. Steps in preparation of carrot yogurt (According to: Salwa et al., 2004) there is a flow chart that shows how an outstanding carrot yogurt could be prepared. Cow's milk for this research was collected from Fayoum district, Egypt (Salwa et al., 2004).

Preparation of carrot yoghurt has also been investigated by other authors all over the world: Cliff et al. (2013); El Samh et al. (2013); Ayar and Gurlin (2014); Agarwal and Prasad (2013) and others. Unlike the Salwa et al. (2004) four levels of carrot juice in yoghurt (8, 16, 24, and 32%) were tested by Cliff et al. (2013). The study investigated Canadian probiotic unsweetened yogurt, its sensory properties and consumer acceptance. Still, beside this, the research explored characteristics and antioxidant capacity of this yoghurt flavored with black carrot (El Samh et al., 2013). In this research, pH value of the yogurt was decreased by flavoring it with black carrot. That proves that black carrot stimulates the starter microorganisms and Befidobacterium lactis B12. In addition, viscosity of yoghurt was decreased after 10 days of cold depository. This yoghurt obtained 97.3 points in average acceptability by consumers. Flavoring ingredients, in this case black carrot increases total phenolics content in yogurt (El Samh et al., 2013). The black carrot was used to improve yoghurt in Ayar and Gurlin (2014) research as well (Figure 2. The production flow chart for flavored spreadable yoghurt (According to: Ayar and Gurlin 2014)).

Next study was accomplished to evaluate the results of stabilizer on the sensory properties including microbial analysis of low-fat frozen yogurt with carrot pulp in the amount of 2%, 3%, 4% and 5% (Agarwal and Prasad, 2013). The conclusion from the results was that the this yoghurt with 3% carrot pulp, 0.5% stabilizer (T3S3) and 4% carrot pulp, 0.5% stabilizer (T4S3) are high in comparison with other treatments.

The typical value of yeast and mould count of different treatment of yoghurt was less than 10/g. It brings to mind that all the samples were of the best quality. Study of the effect of carrot juice on exopolisaccharides (EPS) and β-D galactosidase activity in yogurt (Radiati et al., 2016) demonstrated that the carrot juice highly affects lactic acid amount, pH value, viscosity, β-carotene, EPS, β-D-galactosidase activity, but doesn´t affect significantly on the number of bacteria. During the research the carrot juice increased the yogurt culture activity by increasing acidifying, β-carotene, EPS and β-D-galactosidase, which imply that yogurt could be reinforced with carrot juice.

Smoothie

Making smoothies which included carrots was reported by Andrés et al. (2016a), Andrés et al. (2016b), Andrés et al. (2016c) and Arjmandi et al. (2016).

Conventional thermal processing at high temperature-long time was used in studies of Andrés et al. (2016a), Andrés et al. (2016b) and Andrés et al. (2016c). Carrots were treated at 80°C during 3 min, and after that, smoothie with carrot, melon, orange and papaya was prepared. The color degradation was noticed in Andrés et al. (2016a). Andrés et al. (2016b) observed carrot, melon, orange and papaya smoothie with soymilk added. Heat treatment did not produce any major variations in bioactive compounds. The bioactive compounds of treated smoothies were relatively stable after 45 days of refrigerated storage compared to the fresh product, although the loss of ascorbic acid resulted in decreased antioxidant capacity. Carrot, melon, orange and papaya smoothie with skim milk was made by Andrés et al. (2016c). Total reduction in microorganisms was noticed as well as aroma and acceptability scores were significantly decreased.

Alternative thermal processing – microweave heating, was applied in treatment of carrots during a carrot, lemon, pumpkin and tomato smoothie production (Arjmandi et al., 2016) and the major findings were: 1) increase of the contents of total phenolic compounds and carotenoids, 2) the highest power and the shortest time MWH treatments (3600W for 93 s), resulted into better preservation of antioxidant capacity and vitamin C, and 3) no *L. monocytogenes* growth.

Milk

In the study of Shin et al. (2013) were compared the organoleptic and other qualities of fermented milk having 10 or 15% purple carrot extract previously fermented with *Aspergillus oryzae* or not fermented. In 15% purple carrot extract fermented with *Aspergillus oryzae* viable cell count were significantly higher in comparison with the control after fermentation. Extract of purple carrot fermented with *Aspergillus oryzae* showed a lower red value and higher yellow value in comparison with non-fermented purple carrot extract because of heat-sterilization. From the sensory judgment, 15% purple carrot extract fermented with *Aspergillus oryzae* gained most of the points. To conclude, the best product was made by adding 15% of purple carrot extract fermented with *Aspergillus oryzae* (Shin et al., 2013).

5.2. Jam and jelly

Jams are valuable food products which contain sugars in high concentrations (Habiba and Mehaia, 2008). Jam is gelatinous food product, obtained by cooking of fruits or vegetables pulp with sugar, citric acid and pectin. In addition, jam can be described as a food with intermediate moisture content and can be done by fruit or vegetable pulp being cooked with sugar, pectin, citric acid and additional additives to a sensibly texture. It shall contain at least 65% total soluble solid (TSS) and more than 45% pulp (Manay and Shadaksharaswamy, 2005). During the jam fabrication sucrose is used as a main sugar. All along the production sucrose is inverted to fructose and glucose and it is acceptable to invert 30-40% (Habiba and Mehaia, 2008).

There are two kind of jams: first one is manufactured from pulp of single fruit and the other one is processed by mixing two or more fruits pulp (Manay and Shadaksharaswamy, 2005). Jam of excellent quality has a creamy even consistency without distinct bits of fruit, a shining color, nice flavor and a semi-coagulated texture. The texture is easy to extend but it is without free liquid (Nalinde et al., 2018). Carrot like an excellent point of supply of carotene can be treated into jam as well (Habiba and Mehaia, 2007). Several scientist (Ullah et al., 2018; Nalinde et al., 2018; Habiba and Mehaia, 2008; Roy et al., 2017) were analyzing different jams including carrot jam or carrot jam blends with other fruits/vegetables. The research of Ullah et al., (2018) was done to analysis the jam treatments which were CA0 (carrot pulp 100%), CA1 (carrot pulp 90% + apple pulp 10%), CA2 (carrot pulp 80% + apple pulp 20%), CA3 (carrot pulp 70% + apple pulp 30%), CA4 (carrot pulp 60% + apple pulp 40%) and CA5 (carrot pulp 50% + apple pulp 50%). During physicochemical and sensory analysis it was found that CA5 carrot, apple (5:5) followed by CA4 carrot, apple (6:4) were of good qualities among the treatments. In order to provide health benefits to the customers carrots can be combined with sweet potato in jam production. This jam was found as overall accepted by consumers (Nalinde et al., 2018) (Figure 3. Flowchart for sweet potato jam blended with carrots (According to: Nalinde et al. 2016)).

In other study (Habiba and Mehaia, 2008), during the carrot jam preparation, sugars were replaced with date paste (0, 25, 50 and 75%) and the acquired data showed that by doing so the jam ash was increased as well as protein, total crude fiber and minerals (Ca, Mg, K, Mn, Fe and Zn), and that Na content was lowered. Roy et al. (2017) concluded that carrot jam might be manufactured by using extracted pomelo peel pectin.

Jelly can be made of sugar, citric acid and pectin before adding fruit extract and it´s boiling. Jelly must include minimum 65% of TSS and minimum 45% of fruit fraction (Singh and Chandra, 2012). Research was done to create the fruit jelly by the usage of different levels of guava extract and carrots juice (75:25, 50:50 and 25:75). 75:25 ratio got the best total points for overall acceptability of the jelly and it was awarded as 7.8. In conclusion, the best quality jelly was prepared prepared with guava extract and carrot juice ratio of 75:25 (Singh and Chandra, 2012). Nho et al. (2013) determined the properties and features of jelly in which was added black carrot extract. Their conclusion was that this procedure whit 0.15% ascorbic acid+0.05% NaCl added was excellent soft jelly production.

5.3. Carrot chips

Currently, an accelerated increase in the utilization of snack food has been detected, particularly the snack food from fruits and vegetables (Hiranvarachat et al., 2011), in addition, it has been detected an increasing request for dried products that contain most of their authentic properties (Zheng-Wei et al., 2008) even though they have to experience high temperature and high pressure procedure. During this process it is possible that important degradation of advantageous nutrients is happening (Yi et al., 2018). Chips is considered as one of the most popular snacks. There are two kinds of chips: fried and non-fried chips (Yi et al., 2018). In this moment, a diversity of technologies are developed for restructured chips production, such as extrusion, vacuum frying, freeze-drying and other (Yi et al., 2018).

a.Dehydrated non-fried carrot chips

Best quality of the dried food is characterized by high rehydration, lower bulk mass, small shrinkage, and the high holding of colour and bioactive materies (Zheng-Wei et al., 2008). A lot of drying technologies can be applied in order to get dried carrots without the loss of their with the goal of maintaining their characteristics and nutritive value (Hiranvarachat et al., 2011). The accepted drying methods which are applied for fruits and vegetables are: air drying, solar drying, vacuum drying and freeze drying (Shyu and Hwang, 2011). As opposed to other, freeze-dried products have superior characteristics like super crispness, high retention of nutrients, and minimum shrinkage (Yi et al., 2018). Still, it is accepted that freeze-dried products have superior characteristics: they keep color, aroma, and supplements, good taste, low bulk density, high porosity, better rehydration characteristics in comparison with foods that have passed some of the following drying methods: hot air, vacuum, microwave, and osmotic dehydration (Zheng-Wei et al., 2008). From above mentioned we can see that freeze-drying has a lot of benefits but there is one big problem - long drying time which causes high energy consumption and bigger production costs (Yi et al., 2018). Because of the higher price of this method, it is used for the production of a smaller quantity of superior food and pharmaceutical products (Zheng-Wei et al., 2008).

Major concern within this method is cutting down of the running costs without disturbing the products quality (Zheng-Wei et al., 2008). This can be easily done by connecting it with some of other drying technologies (Yi et al., 2018). For instance, freeze-drying combined with instant controlled pressure drop drying for making restructured carrot-potato chips: optimized by response surface method,was the study conducted by Yi et al., 2018. as well as a study of combined microwave-vacuum and freeze drying of carrot chips that was conducted by Zheng-Wei et al., (2008). Impact of various drying temperatures on the value of dehydrated tiny carrot pieces was investigated by Quartulane et al., (2015). Results show that beta-carotene is not resistant to heat and the quality of foods depends significantly on drying temperature and pre-treatment. It is proven that during the hot air drying there is the highest loss of total carotene (29.4%) (Zheng-Wei et al., 2008). Suman and Krishna Kumari, (2002) found that there was 71% loss of beta-carotene during sun drying, 52% in solar cabinet drying and 42% hot air cabinet drying.

At first moisture contents of the restructured chips varied from 10.08 g/g to 7.23 g/g with lowering of the amount of carrots from 70% to 30% (Yi et al., 2018). Initial moisture contents of the restructured chips were varied from 10.08 g/g to 7.23 g/g with reducing of the amount of carrot from 70% to 30% (Yi et al., 2018). Preparation and quality evaluation of dehydrated carrot slices was also carried out by Gupta and Shukla (2017). From the obtained results, it was found that the Vitamin A content decreased with increase in temperature as well as during storage period. Mondhe et al. (2017) conducted the study on osmotic dehydration of carrot slices and Planinić et al. (2005) studied modelling of drying and rehydration of carrots using Peleg's model.

b.Deep-fried carrot chips

During the year of nineties, carrot chips has been developed by numerous researchers (Slinde et al., 1993; Aukrust et al., 1994, 1995; Baardseth et al., 1995, 1996; Skrede et al., 1997) by means of lactic-acid fermentation (sugar reduction process) and deep-frying in palm oil. Afore mentioned type of fermentation is essential for the chips production having in mind already acquired routines and experience in its performance. However, production process has not been yet fully scientifically treated beyond lactic-acid fermentation and using various temperatures and oils (Sulaeman et al., 2001).

Skrede et al. (1997) discovered that the carotenoids content in carrots remained at the approximately same level as before the production process of chips. Being beneficial to human nourishment, possible increase of the source of provitamin A might be expected due to the frying process in palm oil which contains lipids. Carotenoids content of deep-fried carrots chips in the present study of Sulaeman et al. (2001) were (mg/100 g w/w) lutein, 1964 - 2480; alpha-carotene, 10832 - 15573; beta-carotene, 28958 - 37156; and tentatively identified cis-9-beta-carotene, 9468 - 17987. Presence of cis-9-beta-carotene in the deep-fried carrots chips was also found by Skrede et al. (1997).

Observation of the lactic acid fermentation and its effects on properties of above mentioned product, was conducted in 1993. by Slinde et al.. Colour characteristics were at its maximum when carrot chops were fermented during 24 hours before deep-frying. Amount of reducing sugars was 75% lower after lactic acid fermentation of carrots chops. In 2003. Sulaeman et al. wrote an article about different values of deep-fried carrots chips properties, one among them – carotenoids content.Shyu & Hwang (2011) described development of vaccum frying of carrots slices by central combined rotatable design. This study showed that temperature optimum for this process is from 100 to 105°C and that time optimum from 16 to 20 minutes.

c.Whole grain carrot chips

Norazmir et al. (2014) generated whole grain carrots chips. They pointed out some key data: in 5.00g of the sample of above mentioned product there is 17.573 ± 5.099 percentage of ash, in 2.00g 10.55 ± 2.192 percentage of fat, in 1.00g 7.5 ± 0.141 percentage of unrefined fibers. When it comes to advised fiber consumption, which is 3g per 100g, in above mentioned product there is 7.359 - 7.641g per 100g.

5.4. Carrot seeds

In carrots seeds there are dissimilar compounds in comparison with raw carrots (Seifert et al., 1968). It is known that they contain lots of Ca, P, K, Na, Mg and Al (Özcan and Chalchat, 2007) and carotene which improves lactoperoxidase system microbial activity (Hayashi et al., 2013).

a.Carrot seed oil

According to Emir et al. (2014) cold pressing is the best way to obtain edible carrots seed oil because it is uncomplicated, inexpensive and accessible. Oils obtained in this way are without chemicals, durable, with essential flavor and they contain all bioactive compounds. Further, they have excellent marks by consumers.

In the studies of Özcan and Chalchat (2007) and Parker et al. (2003) some of the properties of carrots seed oil are given: relative mass, unsaponifiable matter content, peroxide and acidity values and fatty acid formation. It is well known that petroselinic acid is ruling and most important fatty acid in *Apiaceae* family which it is valuable for the industry (Dutta, 1992).

There are fourteen compounds in carrots seed oil found by Özcan and Chalchat (2007) among them: carotol and daucol. Jasika-Miaska et al. (2005) classified thirtythree components by GC-MS in carrots seed oil with majors: carotol and β-caryophyllene. Together with daucol they composed 51.5 percent of this oil. According to Gonny et al. (2004) carrots oil from Corsica contains methylisoeugenol, α-pinene and elemicin as main compounds.

b.Essential carrot seed oil

Steam distillation is a process of derivation of essential oils, which are mix of secondary metabolites (Calsamiglia et al., 2017), and which vary in their concentration in plants depending on the plants vegetation cycle, as shown in Damjanović-Vratnica et al. (2011) who found that amount of essential oil obtained from *Satureja montana* L. was higher in May (1.9% w/w) than in

August (1.1% w/w). Also, from the common phytochemical observations and from the results of Damjanović-Vratnica et al. (2016a) it is clear that the preprocessing of plant material plays a significant aspect when it comes to chemicals that the essential oil consists of.

When it comes to the carrots seed essential oil it is extracted from the seeds of carrots and must not be mixed up with the inexpensive macerated - carrot oil made by soaking the carrots material in a base oil (Staniszewska and Kula, 2001). There is 0.59% of essential oil in fresh carrot material (Kataria et al., 2016) and it is yellow in color (Özcan and Chalchat, 2007). There are 34 compounds found in this essential oil (Özcan and Chalchat, 2007). According to Özcan and Chalchat (2007) main components of carrots seed essential oil were carotol (66.78%) and daucene (8.74%). The major compounds identified by in carrot oil were isoprene (84%), caryophyllene (47%) and linalool (38%). Some scientists have found that main compound of carrot seed oil is carotol (Seifert et al., 1968; Özcan and Chalchat, 2007). Also, according to Schaller and Schnitzler (2000), the oil collected from the air dried seed essential oil of Daucus carota L. consist of α- terpinolene, β-caryophyllene, α-pinene, myrcene, α- terpinene and limonene. Aćimović et al. (2016) found out that wild carrot grown in Serbia contained 1.67% of essential seed oil and the cultivated one contained 0.55%. Also, they identified 34 compounds in wild carrot seed essential oil and 51 in cultivated carrot seed oil compounds through GC-MS analyses. When it comes to wild carrot, GC-MS examination of seeds essential oil showd sabinene (40.9%) and α-pinene (30.1%), followed by β-bisabolene (6.2%), β-pinene (5.7%) and trans-caryophyllene (5.3%), as major components, but when it comes to cultivated ones it is found that carotol (22.0%), sabinene (19.6%) and α-pinene (13.2%) are the major compounds.

The combination of beta-farnesene and sesquisabinene consists of 8.2%, the load of trans-caryophyllene is 5.7% and the content of myrcene is 4.7% (Aćimović et al., 2016). According to Özcan and Chalchat, (2007) the carrots seed essential oil yield of cultivated carrots in Turkey was 0.83% and the main component was carotol (66.78%). G-C analysis of the essential carrots seed oil was performed by Ksouri et al. (2015). Carrots seed essential oil had a yield of 3% and carrots folium essential oil had a yield of 2.1%.

Isolation of carrots essential oil was also done by Glišić et al. (2007). They used supercritical carbon dioxide procedure. On the other hand, Abdulrasheed et al. (2015) used soxlet extractor. The colour of extract was yellow and brown in the same time. Authors give the % of yield which was 23,4 and some other chemical properties of obtained oil which was then used for medical soap production. It is shown than this soap can be effective in curing infection caused by Trichophyton rubrum. In comparison with regular medical soaps above mentioned soap was found to be more effective when it comes to infections caused by fungi. This is can lead to minimized costs for soaps preservatives.

c.Effects of carrot seed extract, edible oil and essential oil

Vasudevan et al. (2006) confirmed antinociceptive and antiinflammatory characteristics of wild carrots seeds extract and Rao and Reedy (2013) showed hypoglycaemic and antidiabetic properties of these extracts. It also showed antioxidative and anticancer properties (Shebaby et al., 2013). Different analyses (DPPH and TBARS) showed that wild carrot seed essential oil is good antioxidant and should be recommended as an added ingredient in food and in pharmaceutical industries (Ksouri et al., 2015). Antioxidant characteristics of cold-pressed carrot seed oil was reported by Yu et al. (2005) while antifungal activity of the carrot seed oil and its main sesquiterpene components were investigated by Jasica-Misiak et al. (2014).

Essential oils show antimicrobial properties (Damjanović-Vratnica et al. 2016b, Damjanović-Vratnica et al. 2016c, Bošković et al. 2018, Perovic et al. 2019). Due to the high degree of bacterial resistance to conventional antibiotics, new alternative agents are constantly being explored overcoming this problem. Many studies indicate that essential oils and extracts from plants are a good source of bioactive compounds that show antimicrobial activity against many pathogens. The antimicrobial effect of essential oils and extracts of plants is associated with the content of flavonoids, terpenoids and phenols (Perović et al. 2018). The antimicrobial potential of *Satureja sp.* and *Mentha sp.* from Montenegro was indicated in investigations by Damjanović-Vratnica et al. (2011), Božović et al. (2015). Significant antimicrobial activity of carrots against Staphylococcus aureus, Candida albicans and Alternaria alternate has also been reported (Jasicka-Misiak et al., 2004; Imamu et al., 2007).

CONCLUSIONS

We can conclude that carrots are an indispensable part of human nutrition and that they can be classified as functional food due to their rich chemical composition (β-carotene, vitamins and minerals). They can be consumed raw or in the form of beverages, jam, jelly or carrots chips. It is proven that processed carrots in a form of carrots chips are also rich in β-carotene and, when it comes to whole grain carrot chips, in dietary fibers. Carrots edible seed oil and carrots essential seed oil can also be used.

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