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The effects of drying methods on the characteristics of carrot pomace – a minireview

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Abstract

The processing of fruits and vegetables results in a significant amount of waste and by-products. Due to its high-water content, carrot pomace is susceptible to rapid microbial contamination. In order to avoid the rapid microbial contamination, different drying methods are used. The aim of this paper was to summary and analyze the influence of drying methods on carrot pomace characteristics, according to the papers presented in the literature. The most used drying methods used are convective drying, lyophilization, infrared and microwave drying. They influence in different ways the physico-chemical characteristics of carrot pomace. The carrot pomace has a high content of carotenoids and dietary fibers and appreciable levels of vitamins, minerals and polyphenols. The main components left after drying are directly proportional with the time, temperature and layer of the carrot pomace processed. The best methods of drying that should be choose depending on the type of product in which carrot pomace will be used.

Keywords: carrot pomace, drying methods, nutritional value

1. Introduction

Carrots (*Daucus carota L.*) are one of the most common vegetables grown and consumed worldwide which are frequently used in salads and soups. Also, they could also be commercially processed into various nutritionally rich products such as juice, puree, concentrate, dry powder, canned products, etc. [1, 2].

The production of carrot juice has a rather low yield, therefore about up to 50% of the raw material is transformed into pomace, which is generally eliminated as fodder or even manure [3]. Carrot pomace is a valuable source of bioactive compounds that could be introduced in the food chain in order to develop new nutritionally improved products. Carrot pomace is a rich source of carotene – the precursor for vitamin A, carbohydrates, crude fibers minerals (Ca, P, Fe, Mg) and vitamins (thiamine, riboflavin, vitamin C [3].

The drying methods can affect the functionality of the pomace by changing its chemical composition [4-6]. Drying represent a very efficient method to preserve food ingredients and their quality. This procedure may be beneficial for microbial growth and degradative reactions decrease due to the water activity lowering [4]. One of the main methods of vegetables pomaces drying is the use convective hot air in order to obtain dried products with high quality. In addition, convective hot air drying is very popular in food industry due to its use easiness and relatively good quality of the product obtained [4]. Microwave drying is another alternative that gained more and more popularity because it is a technique easy to control, with good yields. Infrared and lyophilization are modern techniques that can be employed for carrot pomace dehydration.

The aim of this review was to synthetize the effects of the drying methods on the quality of carrot pomace.

2. Chemical composition of carrot pomace

During juice processing, about 30-50% of the amount of carrot results in pomace [7] and thus, about 50% of the carotene is lost [8]. The total

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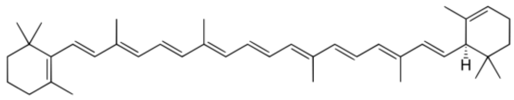
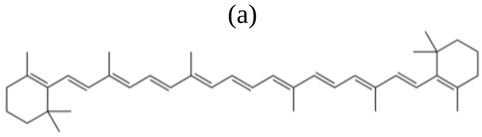
amount of carotene in carrot pomace can reach a value of up to 2 g / kg of substance released, in function of the processing parameters [9]. Carrot pomace has a content between 17 and 31-35% of the total amount of α- and β-carotene (Figure 1) in fresh untreated and bleached carrots, respectively [7].



(a)



(b)

Figure 1. Structure of α-carotene (a) and β-carotene (b) [10]

According to the data presented in study conducted by Tanska et al. [11] on the microelement composition of dried carrot pomace, significant contents of Na, K, P, Ca, Mg, Cu, Mn, Fe and Zn were found. Nawirska and Kwasniewska [12] studied the composition of dietary fiber components in carrot pomace and they revealed high contents of pectin, hemi-cellulose, cellulose and lignin. According to the results obtained by Bao and Chang [7], carrot pomace contains 4-5% protein, 8-9% carbohydrates, 5-6% minerals and 37-48% total dietary fiber, reported to dry matter. Thus, carrot pomace resulted from the extraction of juice represent important sources of compounds with bioactive properties, a characteristic that could be valorized in the development of some functional foods or ingredients and dietary supplements [13, 14]. The use of such a valuable by-product result in a cheaper final product, thus giving a higher profit for both processors and consumers. In order to benefit from carrot-based food products regardless the season, the dehydration process can be used.

Carrot pomace, a product that contains large amounts of β-carotene, could be successfully used to supplement products such as cakes, cookies, bread, biscuits and some extruded products, but also for the manufacture of some types of functional products [1,16-18].

Carrot pomace contains about 85% moisture reported to dry matter and it is thus susceptible to microbial degradation [5, 18]. Its shelf life could be increased by drying or even dehydration for further use in food products [19].

3. Effects of carrot pomace drying methods

Drying of products with high moisture contents represent a complex process, which involves the simultaneous transfer of heat and mass [20, 21]. The changes determined by the drying process of the carrot pomace depend on the selected method (Figure 2).

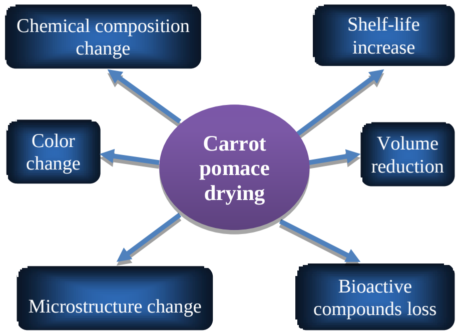


Figure 2. Carrot pomace drying effects

Drying is one of the most effective ways to preserve food and its quality. One of the main advantages is the decrease of the product water activity, which affect the microbial growth and reduces the degradation reactions, leading greater stability. Another advantage of the drying methods is represented by the considerable volume reduction, which led to easier product transport and storage [4, 19]. There are many drying methods, among which it can be mentioned: convective hot air drying, microwave drying, infrared drying, lyophilization. The selected process impacts the physico-chemical characteristics of carrot pomace in different ways, depending on the temperature applied. Thus, the losses of bioactive compounds during drying and the productivity should be considered when choosing a certain method.

3.1. Convective hot air drying

Convective hot air drying is usually employed for fruits and vegetables by-products drying in industrial processes due to its user-friendliness, although it consumes a lot of energy [4].

Alam et al. [19] studied the effects of convective air and solar drying on the quality of carrot pomace. The results obtained showed that the best method was the convective dehydration at 65 °C which led to the highest fiber, total carotenoids, β-carotene contents and minimum change in color, compared to the solar and convective drying at 55 °C [19].

According to the results presented by Kumar et al. [22], the characteristics of carrot pomace and the kinetics of the moisture loss dried in hot air depend on the layer thickness and temperature used. The kinetics of the rehydration process is very important for the quality of the dehydrated food since it is usually consumed or transformed after a prior rehydration [23]. According to the existing data, the rehydration process is directly influenced by the degree of structural deterioration and cell fragmentation [24]. During rehydration of carrot pomace its mass and volume increase and the soluble solid substances are dispersed in water. The convective drying of purple carrot pomace resulted in lower rate of mass increase and loss of soluble components during rehydration [25].

Borowska et al. [26] investigated the effects of convective drying on carrot pomace bioactive compounds and revealed that it had a positive effect on the content of neutral detergent fiber and hemicellulose fraction, total polyphenols and radical scavenging activity by increasing the values found in the dried product. On the other hand, a decrease of the total carotenoids, especially β-carotene was observed [26].

The β-carotene content of two varieties of convective dried carrot pomace, registered a decrease of about 41% compared to fresh carrot. Furthermore, it was stated the presence of small amounts of β-cryptoxanthin and lutein and traces of carotene isomers, with slightly higher amounts reported in dry pomace [26].

Witrowa-Rajchert et al. [27] reported anthocyanin pigments as cyanidin-3-glucoside contents of convective dried purple carrot roots between 238.5 and 563.1 mg/100g, total polyphenols as chlorogenic acid between 1580 and 2766 mg/100 g and TEAC antioxidant capacity between 87.3 and 169.0 mmol Trolox/100 g, depending on the cultivar.

According to Abano et al. [4], the content of ascorbic acid of carrot pomace decreased from 29.34 mg/kg (in fresh pomace) up to 0.80 mg/kg when convective hot air was used. The same authors reported β-carotene values of convective dried carrot pomace between 0.56 and 2.0 mg/kg.

3.2. Microwave drying method

The intensity of the microwave power, the air temperature and the thickness of the sample significantly influence the composition of carrot pomace. In a study conducted by Abano et al. [4], it was shown that the ascorbic acid content of fresh carrot pomace during microwave treatment decreased from 29.34 mg/kg to 1.61 mg/kg. Also in the same study, the degradation of ascorbic acid during drying was investigated and it was proved that in the case of microwave drying it was smaller compared to other drying methods. At the same time, the increase of the effect of microwave power, air temperature and sample thickness led to an increase of ascorbic acid content [4].

The most common carotenoid found in edible plant tissues is β-carotene. It can be used as a dye in the food industry, giving the yellow color specific to the edible carrot plant. During the drying process, the β-carotene content was significantly influenced by the microwave power and sample thickness [4]. The β-carotene content increased with increasing microwave power, air temperature and sample thickness, both in the case of microwave [4]. In the study conducted by Abano et al. [4], it was observed that the β-carotene content for microwave carrot pomace samples varied between 0.93 and 2.05 mg/kg. Most often, the reactions involving β-carotene reduction and oxidation caused by the high number of conjugated double linkages, have been associated to the discoloration and degradation of provitamin power during processing, causing damage of yellow pigments [28]. Degradation of β-carotene has been reported along with provitamin power loss during thermal and oxidation [4, 6].

According to the results obtained by Witrowa-Rajchert et al. [27] on microwave drying of purple carrot roots, the anthocyanin pigments as cyanidin-3-glucoside contents varied between 221.2 and 919.9 mg/100g, the total polyphenols as chlorogenic acid between 1601 and 4211 mg/100 g and TEAC antioxidant capacity between 85.4 and 285 mmol Trolox/100 g, depending on the cultivar.

Hernández-Ortega et al. [29] reported no significant differences on total, soluble and insoluble dietary fiber contents of carrot pomace dried trough microwave or convection air. After microwave drying, the fiber structure remained similar to fresh pomace, while for the pomace dried in a convection oven appeared as long fibers, probably due to the fact that microwave heating enhances the capillary-porous properties of the raw material used [4].

In general, the microwave drying method showed a significant increase in the β-carotene content compared to the convection air technique.

3.3. Infrared drying

Infrared drying is a modern technique that could be applied to carrot pomace in order to decrease its moisture. The principle of this method consists of penetration of the infrared radiation into the material and the energy is transformed into heat [21]. One of the advantages of infrared heating compared to the conventional one is that both exterior and interior layers are heated which led to a high heat and mass transfer rate [30]. Furthermore, the drying time, high efficiency and superior product quality could be achieved by using infrared drying [31, 32].

Doymaz [33] studied the effects of infrared radiation on the drying characteristics and behavior of carrot pomace and concluded that infrared power increase determined drying rate rise and drying time decrease. The results of the effective moisture diffusivity were between 0.59 and 3.40 x 10^{-10} m^2 s^{-1} and registered a proportional increase with the infrared power increase [33].

According to the data obtained by Molnos and Vajda [21] for carrot pomace infrared drying kinetics, a decrease of the drying time from 250 min to 120 min with temperature increase was observed, the raised temperature determined higher moisture loss, linear variation being observed.

Janiszewska et al. [25] studied the effects of infrared – convective drying of purple carrot pomace. Compared to other drying method (microwave, lyophilization) infrared – convective drying resulted in higher time needed to achieve a constant moisture, while the apparent density of the pomace increased after processing [25]. The same authors stated that the vapor absorption of infrared – convective dried purple pomace was lower compared to convective or lyophilization. Higher vapor adsorption capacity of dried pomace led to higher porosity and minor changes of the material structure [25].

Witrowa-Rajchert et al. [27] showed that the use of infrared – convective drying shortened the drying time purple carrot roots by 33% and 13% compared to convection drying, depending on the variety. The anthocyanin pigments as cyanidin-3-glucoside contents of infrared dried purple carrot roots were between 211.4 and 870.3 mg/100g, the total polyphenols as chlorogenic acid between 1448 and 3754 mg/100 g and the TEAC antioxidant capacity between 78.1 and 250 mmol Trolox/100 g, depending on the cultivar [27].

3.4. Lyophilization

Lyophilization commonly known also freeze drying is a method which implies water freeze, followed by its taking away from the pomace, in the first step by sublimation (primary drying) and in the second step by desorption (secondary drying) [34]. Among the advantages of this method, it can be mentioned the minimization of bioactive compounds loss, stability of carrot pomace increase, homogeny dispersion of the components of the dried pomace, easy and rapid reconstitution [35].

Leong and Oey [36] studied the influence of processing methods on anthocyanins, carotenoids and vitamin C of carrots and reported lowering of β-carotene, β-cryptoxanthin, α-carotene, lycopene, lutein, reducing sugars contents after lyophilization, while the amount of vitamin C increased significantly.

In the study conducted by Janiszewska et al. [25], the freeze-dried purple carrot pomace was characterized by the lowest density and the highest rate of vapour adsorption, which led to raised porosity and minimal structural deterioration, compared to the convection dried pomace. The rate of mass increase and loss of soluble compounds of dry carrot pomace during rehydration was the highest for lyophilized sample compared to the convective dried one [25].

According to the data presented by Borowska et al. [26] showed a significant loss of total carotenoids of the lyophilized carrot pomace, the highest decrease being observed for β-carotene. Lyophilization was responsible for a relatively low stability of carotenoids, in particular β-carotene. On the other hand, lyophilization increased the content of phenolics by 20%, while the DPPH radical scavenging increased after lyophilization [26].

Witrowa-Rajchert et al. [27] concluded that purple carrots dried by lyophilization were characterized by about 4 times smaller apparent density, a significantly raised mass increase, and a lower loss of soluble compounds during rehydration compared to the samples dried by convection, infrared radiation or microwave. The anthocyanin pigments as cyanidin-3-glucoside contents of lyophilized purple carrot roots were between 231.9 and 837.9 mg/100g, the total polyphenols as chlorogenic acid between 1459 and 3391 mg/100 g and the TEAC antioxidant capacity between 87.9 and 210 mmol Trolox/100 g, depending on the carrot variety and on the freezing temperature [27].

4. Conclusion

Carrot pomace is a valuable by-product resulted from the processing of carrots juice. Carrot pulp has a high degree of perishability, so different drying methods are used to extend its shelf life. Among the most used drying methods it can be mentioned lyophilization, hot air drying, infrared and microwave drying. The results presented in the literature until this moment showed that the processing conditions significantly affected its nutritional properties. Thus, the temperature, sample layer, the time applied are key factors in keeping carrot pomace bioactive compounds during drying. The drying method should be established in function of the further use of the carrot pomace. The information presented in this paper could be helpful for processors interested in innovative products development using carrot by-products.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest.

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