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PROCESSING METHODS USED FOR ORGANIC VEGETABLE CHIPS - REVIEW

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Abstract

Due to their compounds and their beneficial properties for the body, vegetables are important ingredients in a balanced daily diet. By definition, vegetables are edible parts of the plant that can include: stems, roots, tubers, bulbs, leaves, flowers and beams. It is recommended to eat fresh vegetables, but when this is not possible, they can be preserved in various forms. One of the oldest techniques for preserving vegetables is drying, which involves reducing the water content of vegetables by exposing them to the sun or artificial heat sources. Dried vegetables are produced by different processes. In general, dried vegetables follow the same steps: selection of vegetables according to their shape and quality, peeling, slicing, preservation, dehydration (natural or artificial), sweating or salting, visual inspection and packaging. Drying is beneficial because it extends the shelf life, reduces postharvest waste, and massively helps reduce storage and transportation costs. This article reviews various methods of pre-processing of organic vegetables (cutting forms, different forms of bleaching, etc.) and different drying methods (classic by varying the temperature, vacuum, etc.).

Key words*: organic, vegetables, drying, chips.*

INTRODUCTION

Vegetables are annual or perennial crops with an important role in human nutrition due to nutrient content (vitamins, minerals, fibres, phenolic compounds, etc.). Their consumption can have beneficial effects in the fight against obesity, cardiovascular diseases, diabetes and even different types of cancer (Bahceci et al., 2005; Cruz et al., 2006).

Worldwide, there are approximately 10,000 plants used as vegetables that can be classified in their turn, depending on the edible part, as: green plants (classified as: leafy vegetables with stems and fruits and vegetables with flowers) and roots (classified in their turn in legumes, roots, bulbs and tubers) (Erickson, 2015; Farkas & Hubbard, 2000; Garrote et al., 2004).

Vegetable can be eaten whole or partially, raw or cooked (Aguero et al., 2008). Although the best way to consume most vegetables is in fresh form, vegetable chips are becoming an increasingly popular snack. On the market there are chips made from carrots, parsnips, beets or sweet potatoes, prepared by the traditional method - frying in a hot oil bath (Figure 1).

Figure 1. Vegetable chips from the market (www.nutracheck.co.uk, www.trafochips.nl, www.terrachips.eu)

Besides the classic method of frying in a hot oil bath, drying is one of the oldest techniques for preserving vegetables (Hamid & Mohamed Nour, 2018). This involves reducing the water content of vegetables by exposing them to the sun or to artificial heat sources, or by alternative methods such as freeze drying. Drying is beneficial because it extends the shelf life, reducing microbe development, reduces postharvest waste, and massively helps reduce storage and transportation costs (Lenart, 1996). Dehydrated vegetables are consumed all over

the world and are generally made from potatoes, carrots, celery, parsnips, beetroot, pumpkin, beans or tomatoes. Because some vegetables cannot be dehydrated directly, they are processed as a paste with the addition of salt and spices, after which they are formed and dehydrated (Huang et al., 2011).
Generally, dried vegetables follow the same steps: selection of vegetables according to their shape and quality, peeling, slicing, preservation, drying (natural or artificial), sweating or salting, visual inspection and packaging (Figure 2).

PROCESSING TECHNOLOGIES

In order to obtain chips from vegetables, several stages must be completed (Figure 2): vegetable selection, peeling and slicing, pre-processing, drying, etc. (FAO, 2020; Matz, 1984).

Pre-processing

An important stage to obtain chips is the blanching. Blanching is used to maintain the color, freshness and nutritional quality, stabilize the texture and inactivate the enzymes responsible for producing the unpleasant smell. The process involves thermal inactivation of unwanted benzenes (peroxidase and lipoxygenase), decreasing the rate of enzymatic deterioration of vegetables (Aguero et al., 2008; Bahceci et al., 2005; Cruz et al., 2006; Garrote et al., 2004; Morales et al., 2002; Nissreen and Helen, 2006; Saldivar et al., 2010; Soysal and Soylemez, 2005).
In the study carried out in 2010, Saldivar et al. found that soybean pods retained soluble sugars when steam-blanched for 10 minutes. When blanched samples were quickly frozen, they showed minimal microstructural damage due to the formation of smaller ice crystals compared to unblanched vegetables (Wang et al., 2007). Furthermore, blanching contributes to a better preservation of pigments and can also limit the degradation of chlorophylls and carotenoids (Lisiewska et al., 2004).
Although blanching seems like a wonderful pretreatment, it also causes unwanted changes to the food. Thus, being a thermal process carried out at high temperatures, changes may occur regarding the thermal processing or the loss of soluble nutrients - sugars, vitamins, minerals, etc. (Olivera et al., 2008, Piotr and Waldemar, 2007, Rungapamestry et al., 2007, Song et al., 2003, Volden et al., 2009).
The lowered moisture content provides the chips with good preservation of concentrates for a long time. Various methods can be used, such as sublimation, vacuum, convection or infrared, as such or combined.

Heat drying process

The classic drying method frequently used, and also the simplest, is drying vegetables by electric or solar convection (Mujumdar, 2006). The method involves subjecting the samples to currents of hot air until the amount of water in it is reduced to a minimum. The method comes with many disadvantages, including browning and the decrease in the amount of nutrients in the vegetables due to high temperature air currents.

Infrared radiation (IR)

IR is a form of electromagnetic waves that comes from a heat source which requires no medium for its emission, and is located at the outer range of the visible red light. The infrared radiation wavelength varies from 0.75 to 1000 μm. Infrared radiation can be divided into three different categories, namely near-infrared (NIR 0.75-2 μm), mid-infrared (MIR 2-4 μm) and far-infrared (FIR 4-1000 μm) (Jain & Pathare, 2004). IR drying method uses energy in the form of infrared rays to penetrate food products to a small depth, then turning into heat. Compared to thermal radiation technology, infrared rays have the advantage of lower energy consumption, with increased efficiency. The quality of the final product is also higher, due to the shorter treatment time. The technology also has the advantage of equipment simplicity, adaptability and easy combination with other heating/treatment methods.
In 2021, Ochirov et al. experimented with this technique on carrots. Experimental studies were carried out on an experimental infrared drying plant, in an oscillating mode "heating - cooling" which allows intensifying the drying process and shortening its duration. Recording results on the change in weight and size of carrot slices along the length was carried out

every ten minutes. The resulting carrot chips have a high nutritional value, no significant changes in color, odor and taste after prolonged storage in plastic wrap.

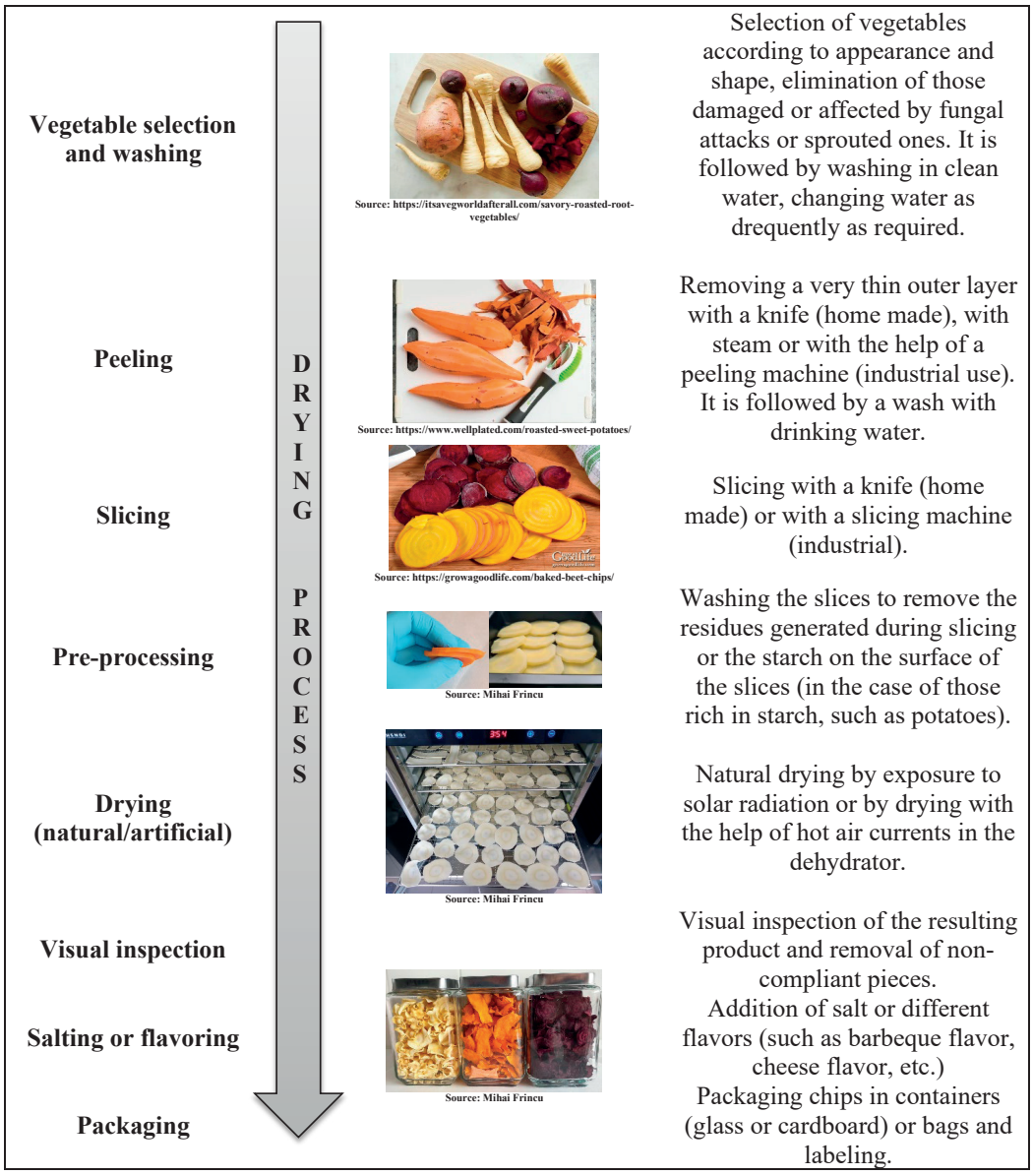

Figure 2. Process of obtaining chips from vegetable (Matz, S. A., 1985; FAO, 2010; Lenart, A., 1996)

Cold drying processes

During lyophilization, the sliced vegetables are first frozen at a very low temperature, after which they are introduced into the device's chamber. At low temperature, under the action of vacuum, the water is transferred from the product to the machine's condenser by sublimation. After all moisture sublimes, a very fine porous structure remains that is easily rehydrated (Fan et al., 2018; Bhatta et al., 2020; Liu et al., 2021).

In 2019, a comparative study between three drying methods (hot-air, combined hot-air-microwave, and vacuum-freeze) was conducted

by Jia et al. The effect of drying methods on sensorial, textural, nutritional, and other quality characteristics of persimmon chips was followed. Their results showed that freeze-dried chips and combined hot-air-microwave technique had the best nutritional and quality scores compared to hot-air dried samples. Therefore, higher amounts of β-carotene, ascorbic acid, total phenol and sugar content were determined in freeze-dried chips. All this led to chips with greater flavor and taste and overall acceptability of freeze-dried chips.

Deep frying

In food production, deep frying is one of the most used techniques. It lends itself to a wide variety of products: from chicken products, fish products, pastries, vegetable chips to French fries. The method involves cooking food at a temperature higher than the boiling point of water in vegetable oil or animal fat (Moreira 2007; Erickson, 2015; Farkas and Hubbard, 2000). The process is based on the simultaneous heat and mass transfers from the oil to the product, a complex process due to two mass transfer operations that take place between the product and the oil when it is fried and vice versa. An example is of products containing starch (potatoes) where starch and water pass from the product into oil, oil which later takes their place in the product (Ziaiifar, 2009; Ziaiifar et al., 2008; Oke et al., 2017).

INFLUENCE OF PROCESSING ON VEGETABLE QUALITY

Vegetable chips

As specified in the introduction there are various vegetables used for chips production, but the most common are: potato, carrots, beetroot, parsnips and sweet potato.

Potatoes chips

Potato (*Solanum tuberosum* L.), with a production of 370 million tons in 2021, is one of the major crops grown worldwide. Potato is produced all over the world, in a huge variety of soils, the first 10 countries in terms of production being: China, India, Ukraine, Russian Federation, United States of America, Germany, Bangladesh, France, Poland, Netherlands (FAO, 2021).

Chips made from potatoes are generally obtained by frying in oil at high temperatures. This process generates large amounts of toxic compounds. In 2015, Mariotti et al. studied different forms of blanching aimed at mitigating the furan and acrylamide formation in potato chips without increasing their oil uptake. Potato slices were blanched between 5 and 15 min, varying the temperature from 50°C to 80°C in order to simultaneously leach out ascorbic acid and reducing sugars, the most important precursors of furan and acrylamide generation in thermally treated starchy foods. After the blanching, potato slices were fried at 170°C up to 98% DM. The optimal variant was the one in which the potato slices were blanched for 17 min at 64°C, conditions in which a significant reduction of furan (91%), acrylamide (54%) and oil content (19%) was observed.

Carrot chips

Carrots is also part of the root crops grown worldwide. Annual production exceeds 44 million tons, and the countries with the highest production are: China, Uzbekistan, USA, Russian Federation, Ukraine, UK and Germany (www.Atlasbig.com). Carrots are used for human consumption as well as animal feed; they are cooked alone as chips or with other vegetables in the preparation of soups, stews, curries, and pies; fresh grated roots are used in salads; tender roots are pickled. Also, Carrots possess many medicinal properties and are used in Ayurvedic medicine. They are a rich source of b-carotene and contain appreciable amounts of thiamine and riboflavin (Ratnadass et al., 1990).

In 2018, Peng et al. studied freezing and its effect as a pre-treatment for carrot chips. They treated carrots in 5 ways: control (4°C for 12 h), 3 variants with freezing at −18, −40 and −80°C for 12 h and a 5th placed in a polystyrene container, was treated with liquid nitrogen for 5 minutes, followed by transfer to the freezer and stored at −80°C for 12 h. After pretreatment, the carrot pieces were dried by Instant controlled pressure drop (DIC). Freezing as a pretreatment at −18 and −40°C led to carrot chips with superior porous structure, relatively low hardness and expected high volume expansion after DIC treatment.

Beetroot chips

In the specialized literature, there is no evidence about the origin of the beet, but it is believed to have originated in the Mediterranean regions and near Asia. With an annual production of approximately 280 tons/year, beet is a widespread plant that is cultivated throughout the year around the globe. The main countries that cultivate it are: Russian federation, France, Germany, USA, Turkey, Poland and China (FAO 2021, www.atlasbig.com).

Various studies have been done on the production process of beetroot chips. Thus, Juvvi et al. studied in 2016 the possibility of obtaining beetroot chips with a lower oil content in the laboratory, using a vacuum fryer. They studied 20 different combinations of temperature, absolute pressure and frying time. They obtained the best results when deep frying beetroot at a temperature between 101 and 110ºC, pressure between 2.9 and 4.4 kPa and 6 minutes of cooking time, with oil content ≤ 15.7 (comparing with 28.41% in traditionally fried beetroot chips) and an overall acceptability ≥ 7.5 compared to 6 for traditionally fried beetroot chips.

Raupp et al. (2011) studied the effect of the drying process on the antioxidant potential and the content of phenolic compounds in beets. To obtain chips, the beet slices were dried in a dehydrator. The optimal drying variant, with a higher content of beneficial compounds, was drying at a high temperature and a shorter time (100 + 90°C/5.6 hours; 90°C/6 hours).

In 2017, Nistor et al. compared 3 combined techniques for obtaining beetroot chips: free convection (at 50, 60, and 70°C), forced convection at 40°C and 315 W microwave power. The aim was to investigate the effect of the drying techniques on the quantity of betalains, polyphenol and microstructure changes (SEM). A strong thermal shock, provided by convection at 60°C followed by microwave wattage 315 W/9 min, leads to a better preservation of bioactive compounds content (0.631 ± 0.0042 mg/g of betacyanin and 0.795 ± 0.0019 mg/g betaxanthin) when compared to convection at 50, 60 and 70˚C. They concluded that combined drying methods led to a significant preservation of the phytochemical content as compared to the traditional methods.

In the next year (2018) Hamid et al. studied the effect of different drying methods on the quality of beetroot chips. They were using three drying methods (sun, oven and freeze-drying), and the chemical composition, minerals, nitrates, betalains, total phenolic, total flavonoid and color were measured for fresh slices and dried chips. At all 3 drying options, the results showed that the chemical composition, total energy, minerals and nitrate of the dried slices were increased compared to that of fresh slices of beetroot. Sun and oven drying of the slices reduced total betalains and betacyanin, instead the content of betaxanthin was increased. Regarding the content of total polyphenols and antioxidant activity, they increased after sun and oven drying but total flavonoids were decreased. In terms of color of the chips powder measurements, the color of the powder obtained from freeze-dried slices was stable compared to other drying methods, the maximum lightness reduction was observed in powder of sun-dried beetroot slices.

Parsnips chips

The parsnip, a plant closely related to carrot and parsley, is part of the root vegetables and is historically dated from the time of the Romans. It has an annual production of approximately 40 million tons/year (FAO, 2021). Although parsnips are a biennial root vegetable, they are generally grown as an annual. The plant has a cream colored tuberous root used mostly boiled, fried, pureed roasted or steamed.

In 2021, Ledbetter et al. studied some novel pre-frying treatment applied to potato, beetroot and parsnip to inhibit the formation of acrylamide, 5-hydroxymethylfurfural (HMF), glyoxal (GO) and methylglyoxal (MGO). Therefore, the slices of vegetables (2 mm for potatoes and 3 mm for parsnip and beetroot) were treated as follows: cold soak (soaking in 2 L of cold tap water for 2 min), hot soak (soaking in 2 L of tap water at 70˚C for 2 min), cold soak followed by hot soak (soaking in 2 L of cold tap water for 2 min, followed by soaking in 2 L of tap water at 70˚C for 2 min) and soaking in 2 L of a 0.01M $CaCl_2$ solution for 2 min followed by blanching at 70˚C in 0.1M citric acid for 2 min.

Soaking in additive solutions was proven to be effective in lowering acrylamide in all tested crisps. However, it significantly increased HMF levels in beetroot and parsnip crisps.

Sweet potato chips

Sweet potato is an important and leading vegetable crop of tropical and subtropical countries. It is considered a native of tropical America. It has an annual production of almost 90 million tones/year, China being the largest producer of sweet potato. Other sweet potato-producing countries are Malawi, United Republic of Tanzania, Nigeria, Angola, Ethiopia, United States of America (FAO, 2021).

In 2019, Sugumaran et al. compared the physicochemical and sensory analysis of sweet potatoes based on different processing methods: deep-fry, freeze-dry, sun dry, air-fry and oven bake methods. The nutritional values of the freeze-dried sweet potatoes had the highest values of ash (1.77 g/100 g), crude protein (5.65 g/100 g) and crude fiber content (3.56 g/100 g) and the lowest amount of fat content (1.51 g/100 g) compared to other samples. They also had good results with oven-dried sweet potato chips, which have moderate amounts of ash, crude fiber and crude protein. Besides, it consists lower fat content compared to deep-fried samples and similar sensory attributes score of range 5 to 6 as deep-fried samples.

CONCLUSIONS

There is a growing demand for organic vegetables around the world now more than ever. With the increase in the number of the population, problems arise in obtaining quality organic vegetable products. A solution could be organic vegetable chips, which are increasingly appreciated by consumers due to their nutritional values and long shelf life. There are several techniques for obtaining chips, each with its advantages and disadvantages. In terms of favourite organic vegetables, sweet potato, carrot, parsnip and beetroot seem to be the favourites of consumers, but also of researchers who use them in their studies.

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