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IMPACT OF COOKING METHODS ON THE AVAILABILITY OF NUTRIENTS IN FOODS OF PLANT ORIGIN

IMPACTO DOS MÉTODOS DE COCÇÃO NA DISPONIBILIDADE DE NUTRIENTES EM ALIMENTOS DE ORIGEM VEGETAL

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ABSTRACT

Cooking methods can affect the nutrients in food, a practice that can improve the availability of seasonal products, but also affect quantities such as original nutritional and sensory properties. The objective of this work was to provide an overview of the impact of different cooking methods on the availability of nutrients and sensory aspects in products of plant origin. For the review, a bibliographical search was carried out in some databases using the descriptors “cooking methods”, “cooking treatments”, “domestic processing”, “vegetables”, in the period from 2012 to 2023. 7459 articles were found, which after applying the inclusion and exclusion criteria resulted in 25 articles. The tubers showed better results when boiling compared to steaming, due to the characteristics of starch, which requires water to gelatinize, thus increasing digestibility. Cooking with skins improved antioxidants, reducing the fact that consuming potatoes with skins can preserve essential nutrients. However, processing legumes can lead to loss of micronutrients due to chemical changes or leaching by water. In relation to sensory aspects, it is stated that the cooking process, in general, causes shine, increases softness and promotes darkening of the color. In short, food preparation methods directly influence the availability and preservation of nutrients. The careful choice of cooking methods can be an effective strategy to preserve the essential nutrients in foods of plant origin, contributing to a healthier and more balanced diet.

Keywords: antioxidants; culinary preparations; food technology; processing; vegetables.

RESUMO

Os métodos de cocção podem afetar os nutrientes dos alimentos, uma prática que pode otimizar a disponibilidade de produtos sazonais, mas também afetar negativamente as propriedades nutricionais e sensoriais originais. O objetivo deste trabalho foi fornecer uma visão geral sobre o impacto dos diferentes métodos de cocção na disponibilidade de nutrientes e aspectos sensoriais em produtos de origem vegetal. Para a revisão, foi realizada uma pesquisa bibliográfica em algumas bases de dados utilizando os descritores “cooking methods”, “cooking treatments”, “domestic processing”, “vegetables”, no período de 2012 a 2023. Foram encontrados 7459 artigos, que após aplicação dos critérios de inclusão e exclusão resultaram em 25 artigos. Os tubérculos mostraram melhores resultados na fervura em comparação ao vapor, devido às características do amido, que requer água para gelatinizar, aumentando assim a digestibilidade. O cozimento com cascas melhorou os antioxidantes, indicando que consumir batata com casca pode preservar nutrientes essenciais. No entanto, o processamento de leguminosas pode levar à perda de micronutrientes devido a alterações químicas ou lixiviação pela água. Em relação aos aspectos

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sensoriais, a revisão demonstrou que o processo de cocção, de forma geral, ocasiona diminuição do brilho, aumento da maciez e promove o escurecimento da cor. Em suma, os métodos de preparação dos alimentos influenciam diretamente a disponibilidade e a preservação dos nutrientes. A escolha criteriosa dos métodos de cocção pode ser uma estratégia eficaz para preservar os nutrientes essenciais dos alimentos de origem vegetal, contribuindo para uma alimentação mais saudável e equilibrada.

Palavras-chave: antioxidantes; hortaliças; preparações culinárias; processamento; tecnologia de alimentos.

INTRODUCTION

Food processing dates to antiquity, representing an essential practice that has evolved over time (ZHAO *et al.,* 2020). The processing of vegetables, in general, aims to achieve a variety of objectives, resulting in both desirable and undesirable consequences. On the positive side, it is important for food safety, product durability, extending shelf life, and mitigating microbiological risks (VERRUCK, 2020). Additionally, it leads to improvements in nutritional value, enhancing the availability of essential nutrients (NAYAK; LIU; TANG, 2015).

In the specific context of vegetable processing, this practice can optimize the availability of seasonal products but also raises concerns regarding the maintenance of original nutritional and sensory properties (SAFRAID *et al.,* 2022). Some studies demonstrate that processing impacts coloration, induces changes in physical properties such as texture, nutrient losses, chemical composition, and enzymatic modifications (CHANG *et al.,* 2021).

Vegetables are considered essential pillars for health promotion due to their richness in nutrients. They stand out as potent reservoirs of antioxidants, which combat free radicals and protect cells against damage (AMITAVA; KIMBERLY, 2014). The significant presence of fiber and water contributes to gastrointestinal health, aiding in digestion and the prevention of digestive tract-related diseases (HOSSAIN *et al.,* 2017). Additionally, they offer a wide range of vitamins, including β-carotene (provitamin A), thiamine (B1), riboflavin (B2), niacin, pyridoxine (B6), pantothenic acid, folic acid, ascorbic acid (vitamin C), and vitamins E and K. Each of these vitamins plays specific roles in metabolism, immunity, and the maintenance of physiological balance (FABBRI; CROSBY, 2016). In addition to vitamins, vegetables are also an important source of essential minerals such as calcium, iron, potassium, magnesium, and zinc, which play fundamental roles in bone health, muscle function, blood pressure regulation, and many other physiological processes (TIWARI; CUMMINS, 2017).

However, this diversity of nutrients can be affected by the cooking method employed. It is known that nutrient losses occur during preparation and cooking phases, making it important to understand how these losses occur to help consumers reduce losses and improve the nutritional quality of preparations (FENG *et al.,* 2014). The most common methods used for cooking vegetables are steaming, baking, boiling, frying, sautéing, microwave cooking, and pressure cooking (FABBRI;

CROSBY, 2016). It is also known that nutrient losses can occur during preparation phases, involving washing, peeling, cutting, and chopping (SUN *et al.,* 2021).

Many studies have been conducted to investigate the impact of preparation and cooking methods on the stability of food nutrients. The results of these studies demonstrate changes in vegetable composition, with some methods resulting in nutrient loss and others increasing availability (HERNÁNDEZ *et al.,* 2022; BOTELLA *et al.,* 2023; HUERTAS *et al.,* 2022). For example, Frankova *et al.* (2014) demonstrated, analyzing sweet potatoes, that total phenolic compounds were higher in sous vide cooking, believed to be related to the absence of direct contact between food and water, thus water-soluble anthocyanins remain in the product.

Temperature changes can modify the taste, texture, and appearance of foods. Paciulli *et al.* (2017) demonstrated that steam cooking under controlled time/temperature conditions could be proposed as an alternative method to traditional steam cooking, as it was observed that Brussels sprouts had higher phenol content, preserving their quality, becoming softer, and greener in color after cooking.

The cooking of vegetables can affect bioactive compounds, substances known for their beneficial health properties, which can act as antioxidants, activate enzymes, block toxin activity, and inhibit cholesterol absorption (QUEIROZ, 2012). Among the bioactive compounds that give functionality to vegetables are soluble and insoluble fibers, polyphenols, carotenoids, tocopherols, tocotrienols, phytosterols, isoflavones, organosulfur compounds, and plant steroids and phytoestrogens (CHAVES, 2015).

In this context, this review aimed to provide an overview of the impact of different cooking methods on nutrient availability and sensory aspects in vegetables, legumes, and tubers.

METHODOLOGY

The present research consists of a narrative literature review on processing and cooking methods and their relationship with nutrient bioavailability and sensory aspects in vegetables, legumes, and tubers. According to Rother (2007), narrative review articles are comprehensive publications suitable for describing and discussing the development or "state of the art" of a particular subject from a theoretical or contextual point of view.

The search for articles was conducted by a team of two individuals and took place in the Scientific Direct (ELSEVIER) and Medical Publications (PUBMED), Web of Science databases. The following Medical Subject Headings (MeSH) descriptors were used: "*cooking methods*", "*cooking treatments*", "*domestic processing*", "*vegetables*", and their Portuguese equivalents: "*métodos de cozimento*", "*tratamentos culinários*", "*processamento doméstico*", and "*vegetais*".

The team used a rigorous search strategy to ensure the breadth and quality of the articles selected for inclusion in the review, adopting inclusion and exclusion criteria. The search sequence used was (cooking methods) OR (cooking treatments) OR (domestic processing) AND (vegetables) NOT (animal feed). Articles published between 2012 and 2023 in English and Portuguese, which presented the descriptors mentioned in the title and/or abstract, were included. Theses, dissertations, review articles, protocols, recommendations, and articles not available in full text were excluded. All selected articles were reviewed by the team's supervisor to ensure the consistency and reliability of the selection process. The review was conducted from August to December 2023. For the description of the selected articles, a table was prepared containing author(s)/publication year; food items; cooking method, cooking conditions (temperature and time); preparation method, and main outcomes found.

RESULTS

A total of 7459 articles were found through the crossing of descriptors and the use of filters mentioned in the methodology. Of these, 7425 were excluded based on title reading, 7 based on abstract reading, and 2 after detailed article reading, resulting in 25 articles that met the objective of this research. Among the studies found, 19 analyzed vegetables, 2 legumes, and 4 analyzed tubers (Table 1).

Table 1 - Effects of processing and cooking methods on the nutrients of tubers, legumes, and vegetables.

Food	Cooking method	Cooking conditions	Preparation	Main outcomes found	Reference
Tuber					
Potato	Boiling, baking, and microwave	Boling: 100°C/50 to 60 min; Baking: 250°C/60 and 220ºC/65 min; Microwave: 25 min/700W and 35 min/560W Whole,	Greater weight loss in baking.	- Greater weight loss during baking. - Starch gelatinizes more rapidly in the microwave. - Sugars (fructose, glucose, and sucrose) increased during baking and in the microwave. - Bioactive compounds were better preserved when the food reached lower temperatures.	Yang *et al.* (2016)
White, orange, and purple potatoes.	Baking, boiling and Sous Vide	Boil: 90ºC for 100 min; Bake: 190°C for 70 min; SV: 85°C for 100 min	Whole with shell	- Purple sweet potatoes had almost twice as much antioxidant capacity as white and orange samples. - The highest antioxidant capacity was obtained by the SV method in purple samples, due to the higher phenolic content and greater quantity of phenolic acids.	Guclu *et al.* (2023)

Purple, red and yellow potatoes	Boil, microwave, baking	Microwave: 10min/750W; Oven: 45 min, 180°C; Boil: 15min	With shell, without whole shell and in pieces	- The ascorbic acid content was reduced in all cooking treatments. - Losses of ascorbic and chlorogenic acid were minimized in peeled and boiled tubers, as well as total anthocyanin levels were the highest in this treatment. - Cooking increased total anthocyanin levels in all cultivars compared to raw tubers.	Lachmane *et al.* (2012)
Purple sweet potato	Steaming, boiling and baking	Cooking: 100ºC/40 min Steam: 100ºC/30 min Baking: 200ºC/90 min	Shelled pieces	- The phenylpropanoid content in purple potatoes increased significantly after cooking. - The steamed sample showed the greatest changes in starch (degraded from 53.01% to 39.5%) and increase in soluble sugar (increased from 11.82% to 29.08%).	Jiang *et al.* (2023)
Legumes					
Lentils, black beans and kidney beans	Immersion and boiling/maceration and boiling.	2 hours soaking and 20 minutes boiling; 2h maceration and 40 min boiling.	Whole grains	- They demonstrate considerable loss of phenolics during processing in water and the large loss depends on the legume. - Cooking reduces heat-sensitive compounds such as anthocyanins.	Giusti *et al.* (2019)
Beans	Boiling, pressure cooking and steaming.	Immersion: 14h, room temperature/ 85 to 100 min boiling: 40-50 steam/ 20-25 pressure	Whole grains	- The loss of zinc in the boiling water was greater than the loss of iron.	Huertas (2022)
Vegetables					
Mustard leaves	Double boiler, stove and microwave	Microwave: 5min; Stove and bain-marie: 20 min	Cut	- The microwave cooking had the highest reduction in potassium. - Microwave cooking caused the greatest nutrient loss, followed by stovetop cooking.	Lima *et al.* (2019)
Dark green leaves	Boiling, steaming and frying	Boil: 5 min; Frying: 170ºC; Steam 5 min.	Chopped	- Frying led to a reduction in the primary bioactives and antioxidant activities in all tested leafy vegetables. - Leaves steamed and boiled exhibited higher levels of polyphenols, flavonoids, and antioxidant capacity compared to fresh leaves.	Gunathilak*et al.* (2018)
Purple eggplant	Baking, baking, frying and grilling.	Cooked: 100°C/20 min; Grill: 120°C/10min; Bake: 180°C/30min; Frying: 170°C/ 10min	Cut into slices	- Cooking processes cause degradation of phenolic compounds, but increased bioaccessibility. - Cooking promoted the release of phenolic compounds from food matrices during digestion.	Martini *et al.* (2021)

Cress	Boil, microwave and steam	Boil: 90ºC (2.5 and 10 min); Microwave: 1400W (1,2 and 3 min); Preheated steam: 100º (5, 10 and 15 min)	Chopped	- In steam, there was a greater amount of total phenols, compared to boiling, which saw a decrease in phenolics. - Boiling increased the concentration of carotenoids. - Microwaves and steam did not affect carotenoids. -Microwaves and steam retained most of the phytochemicals.	Giallourou *et al.* (2016)
Purple cabbage	Steam, microwave, boil and fry	Boil: 5 min; Fry: 130ºC/5 min; Microwave: (450W) /5 min; Steam: 5 min	Pieces	- Boiling caused loss of phenolic content and reduced vitamin C. -All cooking methods caused a significant reduction in the levels of anthocyanins and total glucosinolates. - Steaming resulted in significantly greater retention of the radical scavenging activity of vitamin C and DPPH.	Xu *et al.* (2014)
Purple cabbage	Minimally processed, boil, steam, microwave and sauté	Boil, steam and sauté: 5 min and microwave: power 450W/5 min	Chopped	- All cooking methods caused a significant reduction in the levels of anthocyanins and total glucosinolates. - Frying and boiling reduced vitamin C, while steaming and microwave heating had similar levels to the minimally processed group. - Consumed fresh in salads, maintains higher levels of nutrients.	Feng *et al.* (2014)
Cauliflower	Boil, steam, microwave and conventional braised	Boil: 5min; Sauteed: 3 to 5 min; microwave: 5 min; Steaming: 5 min	Cut into homogeneous pieces	- Steam can be considered the best cooking method, as it preserves bioactive compounds (phenolics, glucosinolates, carotenoids and chlorophylls) and antioxidant activity. - Frying provided the highest degradation rate for all phytochemicals. - Water-soluble phytochemicals (ascorbic acid and free phenolics) were significantly decreased by boiling.	Akdas, Bakkalbasi, (2017)
Cauliflower	Boiling, cooking and steaming	Steam: 10 min; Boil: 10 min, 98°C	Divided into individual flower	- Steam cooking increased phenolic compounds. - Cooking methods caused a loss of glucosinolates, especially in boiled samples.	Girgin, Nehin (2015)
Chayote sprout	Frying, microwaving, steaming and blanching	Microwave: 3 min; Frying: 150°C for 5 min; Steam: 8 min; Blanching: 2 min boiling	Chopped	- Steam cooking is the ideal cooking method, as it allows a significant retention of phenolics, flavonoids and β-carotene. - Microwave is recommended to preserve bioactive compounds (phenolics, flavonoids and β-carotene).	Chang *et al.* (2021)

Carrot	Steaming, boiling, braising and frying	Steam, boil, sauté and fry: 110°C 5/10/15 min	Cut into slices	- Steaming enhanced the flavor of the carrots. - The heat conduction cooking method with water improved the visual quality of the carrots, while the oil method had the opposite effect. - Cooking processes affected the color of carrots - None of the four methods achieved a loss of total monomeric carotenoid content in carrots.	Shihan *et al.* (2023)
Brussels sprouts and Pumpkin	Steam and air	25 min at 90°C for Brussels Sprouts and 10 min at 110°C for pumpkin	Pieces and cubes	- The application of air/steam cooking preserved the physical or antioxidant properties at all temperatures. - Phenol values of air/steam cooked pumpkin increased compared to raw pumpkin. - Air/steam cooking preserved physical and antioxidant properties at all temperatures.	Paciulli *et al.* (2017)
Pumpkin	Boil, steam, conventional oven and microwave	Boil: 10min; steam: 20 min; Oven: 180°C/10min, microwave 5 min/800W	Shelled pieces	- Boiling caused the greatest losses of L-AAs, while baking and microwaving caused about 80% or more increases in L and D-Trp. - Cooking pumpkins in the microwave preserved almost all of the amino acids.	Botella *et al.* (2023)
Broccoli and cauliflower	Microwave and freezing	Microwave: 1000 W for 1 and 10 min; 950 W for 19 min and Freezing 4ºC	Broccoli flowers	- Deep freezing causes hydrolysis of glucoraphanin into sulforaphane after thawing, thus improving the nutritional value of broccoli. - Freezing can prevent glucoraphanin losses.	Sun *et al.* (2021)
Broccoli, carrot and cucchini	Boiling, steaming, combination oven and microwave cooking	Cooking time ranged from 4 to 19 minutes	Broccoli Flowers and Carrot and Zucchini Pieces	- For the three vegetables, microwave cooking presented the worst results in relation to global acceptance. - The carrot flavor did not differ significantly between cooking methods. - Broccoli cooked in the microwave showed marked degradation of chlorophyll.	Castro *et al*. (2020)
Broccoli	Saco de micro-ondas	5 minutes	Broccoli flowers	- The content of hydroxycinnamic acid derivatives was reduced during microwave cooking. - Broccoli cooked in a microwave bag showed greater retention of glucosinolate content and greater antioxidant capacity compared to microwaved without a bag.	Paulsen (2021)

Broccoli	Fervura, micro-ondas e vapor	1,3,5 and 10 minutes at 98ºC.	Broccoli flowers	- The total polyphenol content increased to 12% in the microwave at 5 min and decreased to 60% in boiling at 10 min. - Total ascorbic acid, the greatest loss was observed for boiling. - Vaporization preserved and increased the content of ascorbic acid, phenolic compounds and antioxidant activity.	Andez *et al.* (2022)
Broccoli	Boil, steam, sauté, fry/sauté, and microwave	Boil, steam, Saute: 5 min/140°C; microwave: 5 min/1000W; Fry: 2 min/170°C and /3 min boil	Broccoli flowers	- Except for steaming, all cooking methods have resulted in a significant loss of vitamin C. - Steam cooking maintains the glucosinolates in broccoli. - Microwaves, steaming and sautéing maintained the carotenoid content after cooking, while boiling and frying caused loss.	Soares, Oliveira, Raposo (2017)
Broccoli	Boil, steam and microwave	0, 1, 3, 5 and 10 min	Broccoli Flowers	- Total polyphenol content increased to 12% in microwave at 5 min and decreased to 60% in boiling at 10 min. - Boiling showed a decrease in all analyzed compounds, while steaming for 10 minutes showed an increase in ascorbic acid, phenolic compounds and antioxidant activity. - Regarding total ascorbic acid, the greatest loss was observed with boiling - 10 min vaporization showed an increase in antioxidant activity. - Boiling and blanching result in the greatest loss of glucoraphanin.	Hernández *et al.* (2022)

Source: Sous Vide (SV).

DISCUSSION

Most vegetables require some form of cooking prior to consumption. These cooking processes induce changes in chemical composition that can modify the concentration of their bioactive compounds and their bioavailability (ANDEZ *et al.,* 2022). Generally, when analyzing outcomes regarding the optimal cooking method, steaming emerges as an advantageous option for vegetables in terms of nutrient preservation, as demonstrated in the studies by Girgin and Nehin (2015), Shihan *et al.* (2023), and Chang *et al.* (2021).

1. TUBERS

Several studies have analyzed the influence of cooking methods on potatoes (LACHMAN *et al.,* 2012; YANG *et al.,* 2016; JIANG *et al.,* 2023; GUCLU *et al.,* 2023). In tubers, boiling showed better results compared to steaming, owing to the intrinsic characteristics of tubers, which, containing starch, require water for gelatinization; thus, the boiling method enhances digestibility. Samples of baked and microwave-cooked potatoes showed lower total starch contents compared to boiled potatoes, likely due to variations in the gelatinization process during microwave and boiling compared to the boiling process (YANG *et al.,* 2016).

Potatoes are a significant source of natural antioxidants such as vitamins, carotenoids, flavonoids, and phenolic compounds, besides being rich in starch. These antioxidants have the potential to reduce the risk of various diseases such as cancer, cardiovascular diseases, cataracts, and muscular degeneration (FRIEDMAN, 1997; CHUAH *et al.,* 2008). Different cooking methods affected the antioxidant activity of potatoes, resulting in significant reductions or increases (BLESSINGTON *et al.,* 2010; NAVARRA *et al.,* 2010; GUCLU *et al.,* 2023). Lachman *et al.* (2012) reported that for pigmented potatoes, thermal treatment did not cause any changes in the phenolic acid content, while anthocyanins showed only a slight decrease (16-29%) with cooking treatments and concluded that boiling combined with prior peeling was the most favorable method among the tested cooking treatments.

The highest total phenolic acid content was found in orange-fleshed sweet potato baked in the oven, while the lowest amount was quantified in white-fleshed sweet potato boiled. Previous studies reported that some phenolics leach into the water in significant amounts during boiling, resulting in a decrease in the nutritional value of foods (MARTINI *et al.,* 2021).

Blessington *et al.* (2010) demonstrated that antioxidant activity in the pulp increased after all tested cooking methods compared to raw potatoes, with microwaving being the most effective. This increase may be related to changes in starch texture during cooking, allowing for greater protection of antioxidant compounds from the cellular matrix (BLESSINGTON *et al.,* 2010). Processing can result in higher recoveries of antioxidant compounds and simultaneously inactivate enzymes that degrade antioxidants during processing (NAVARRA *et al.,* 2010). Cooking had a positive impact on the antioxidant compound content in potato skins. Yang *et al.* (2016) pointed out that consuming potatoes with skin may be a strategy to preserve nutrients.

2. LEGUMES

The consumption of legumes involves cooking, often preceded by a water soaking step to reduce cooking time. Despite the significant impact expected from consumption, there is a scarcity of studies on the phenolic profile in cooked legumes (GIUSTI *et al.,* 2019). Kalogeropoulos *et al.* (2010) addressed this gap by analyzing phenolic compounds in 14 varieties of cooked legumes, observing a reduction in their concentration after cooking. These results highlight the need to explore the effects of thermal processing on the nutritional properties of legumes, considering the common practice of soaking before cooking. Soaking overnight is a traditional preparation method adopted worldwide (CASTILLO *et al.,* 2012).

During food processing, micronutrients can be lost in various ways. Chemical alterations such as oxidation and thermal degradation can result in the loss of essential vitamins and minerals. Additionally, physical losses are also common, especially through leaching into cooking water. The latter is a particularly significant concern when cooking legumes, where part of the nutrients can be solubilized and lost to the surrounding liquid (OLIVEIRA *et al.,* 2001). Besides direct losses during processing, mineral absorption can be compromised due to the common presence of antinutritional factors in the food matrix. These include substances such as phytates, oxalates, and tannins, which can bind to minerals and reduce their bioavailability to the body (RAMÍREZ-CÁRDENASI *et al.,* 2008). As a result, even though plant foods are nutrient-rich, the body's ability to absorb and utilize these nutrients may be limited.

Various antinutritional compounds such as phytic acid, polyphenols, lectins, and tannins have been identified in beans as major obstacles to the bioaccessibility and bioavailability of iron and zinc for the human body (ARIZA-NIETO *et al.,* 2007; RAMÍREZ-CÁRDENASI *et al.,* 2008; CASTRO *et al.,* 2020; FIGUEIREDO *et al.,* 2017; ZHANG *et al.,* 2020).

3. GREENS

Studies have addressed different cooking methods and their impact on the antioxidant and nutritional compounds of vegetables, focusing on varieties such as cauliflower, chayote, and purple cabbage (Table 1). Regarding cauliflower, it was observed that steaming resulted in a significant increase in phenol content, indicating more effective preservation of these antioxidant compounds compared to boiling (GIRGIN; NEHIN, 2015). Additionally, during steaming, antioxidant capacity, measured by the DPPH (2,2-diphenyl-1-picrylhydrazyl) method, also increased considerably. This cooking method also favored the release of alpha-carotene from the matrix, due to the denaturation of carotenoproteins, resulting in higher extractability and elevated concentrations in steamed cauliflower samples (BOHM *et al.,* 2002; GLISZCZYNSKA-SWIGLO *et al.,* 2006).

According to the study by Gliszczynska-Swiglo *et al.* (2006), there was a 21% increase in antioxidant capacity in samples of steamed cauliflower. The main mechanisms responsible for the increase in total phenolic content in vegetables cooked by steaming likely involve softening and rupture of cellular components, resulting in the release of antioxidant compounds (PELLEGRINI *et al.,* 2009).

On the other hand, boiling and frying resulted in significant reductions in vitamin C content in purple cabbage, while steaming and microwave heating showed no notable losses compared to the minimally processed group (FENG *et al.,* 2014). The boiling method, in particular, was associated with large losses of vitamin C and polyphenols due to leaching of these compounds into the surrounding water. Therefore, using the least amount of water possible and shorter cooking times are recommended to preserve vitamin C contents (ERDMAN; KLEIN, 1982). This negative effect of boiling on nutritional values was observed in vegetables of the Brassica genus, such as kale, broccoli, cabbage, Brussels sprouts, and cauliflower, known for their antioxidant activity attributed to the content of polyphenolic compounds and vitamin C (SIKORA *et al.,* 2008).

Regarding glucosinolates, all cooking methods had a significant impact on their content (FENG *et al.,* 2014). Finally, it was highlighted that the steaming cooking method had minimal negative effects on the nutritional quality of purple cabbage, indicating that consuming this freshly cut vegetable in salads can preserve its nutritional quality (FENG *et al.,* 2014). Thus, although studies have observed varied impacts of different cooking methods on the antioxidant and nutritional compounds of the analyzed vegetables, steaming appears to be a preferred option for preserving these components, especially in varieties such as cauliflower and purple cabbage.

4. EFFECT OF COOKING TECHNIQUES ON SENSORY ASPECTS

The color of foods plays a significant role in providing information about the quality, ripeness, and sensory characteristics of food products. Additionally, it is one of the primary sensory elements that impact consumers' food preferences and choices (SELANVARZI *et al.,* 2021; ZHANG; WANG., 2017). Therefore, it is important to closely monitor changes in food color during the preparation and cooking process.

Regarding the effect of cooking techniques on the texture, appearance, and color of vegetables, Brussels sprouts cooked in air steam became softer and less green, while in pumpkin (*Curcubita moschata*), there was a yellowish darkening (PACIULLI *et al.,* 2017). In Purple Sweet Potatoes (*Ipomoea batatas*), color was measured through different cooking methods (steamed, boiled, and baked), and in all methods, there was a significant decrease in brightness, and the size after cooking became smaller compared to the raw sample (JIANG *et al.,* 2023).

In terms of consumer acceptance, the preferred cooking method was boiling for broccoli, while for zucchini and carrots, it was microwave and steam. For all three vegetables, microwave cooking had the worst results in terms of overall acceptance regarding color and texture (CASTRO *et al.,* 2020). The impacts of various processing methods on color and the content of pigmented phytochemicals in carrots and their products have been extensively investigated in various studies (FERRENTINO; SPILIMBERGO, 2015; GONG *et al.,* 2015; LYU *et al.,* 2021; SALEH *et al.,* 2022).

In carrots (CASTRO *et al.,* 2020), it was observed that the color deteriorated rapidly after 4 minutes of cooking. This change in coloration can be attributed to the fact that higher temperatures can cause destruction and elimination of pigments, as well as accelerate enzymatic browning and Maillard reactions, as discussed by Rajkumar *et al.* (2017).

CONCLUSION

The food preparation process plays a significant role in either preserving or losing essential nutrients. The sensitivity of nutrients to temperature varies, and some substances are more susceptible to changes during cooking. It is noteworthy that temperature changes not only affect nutritional values but also promote modifications in taste, texture, and appearance of foods. Additionally, the solubility of certain nutrients in water can result in losses during the cooking process. Thus, when choosing food preparation methods, it is fundamental to consider not only the desired taste and texture but also the maintenance of essential nutrients. Depending on the food matrix and nutritional composition present in the food, the most suitable method should be observed. Awareness of the changes that occur during the cooking process highlights the importance of studies aimed at investigating the best cooking methods and processes to ensure maximum preservation of the nutritional benefits of foods.

CONFLICT OF INTEREST

“The authors declare no conflicts of interest in this work.”

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