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Research Article

# Assessment of the Effect of Different Cooking Methods on the Content of β-carotene in Carrots, Folate in Asparagus, and their Physical Properties

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## ABSTRACT

Among the various cooking methods, steam cooking and microwave heating are widely utilized. It is crucial to evaluate these methods in terms of their impact on the nutritional and vitamin content of foods, as well as on their sensory attributes. This study aimed to assess the effects of steam and microwave cooking on the vitamin content and physical attributes, such as color and texture, of vegetables. Specifically, carrots were selected for their β-carotene content, a fat-soluble vitamin, while asparagus was chosen for its folate content, a water-soluble vitamin. The objective was to determine the loss of these vitamins and the corresponding changes in color and texture. Vitamin loss was quantified using high-performance liquid chromatography coupled with a UV detector (HPLC-UV). Texture changes were measured with a texturometer, reporting shear force in Newtons (N), and color changes were analyzed using a Computer Vision System (CVS) with subsequent analysis of the color parameters L*, a*, b*, ΔE, hab, and C*. The results showed that microwave cooking of carrots retained an average of 73% of β-carotene, whereas steam cooking retained 64%. For asparagus, steaming preserved 58% of folate compared to 41% retained after microwave cooking. Shear strength in carrots decreased by approximately 10% under both cooking methods. However, in asparagus, shear strength reductions were more pronounced, decreasing by 25% with steaming and 38% with microwave cooking. Significant differences ($p<0.05$) in color parameters were observed over time for both vegetables. Statistical analysis indicated a strong correlation between vitamin loss and changes in color (ΔE, hab, C*) and texture. The evidence suggests that steam cooking better preserved folate, texture, and color, while microwave cooking resulted in lower carotenoid loss in carrots. These findings can inform optimal food preparation practices in both commercial and domestic settings.

**Keywords:** Steaming; Microwave; β-carotene; Folate; Texture; Color

## INTRODUCTION

Food quality is often linked to its external and visible characteristics [1]. However, preserving the nutritional composition of food is crucial for maintaining consumer health [2,3]. Despite significant public health efforts addressing over-nutrition, micronutrient deficiencies remain a hidden issue, particularly among children and adults. Understanding food transformation processes and developing guidelines to minimize nutrient loss during thermal processing is essential [4-6].

Our study investigated the hypothesis: "Controlled steam cooking results in lower loss of β-carotene in carrots and folates in asparagus, as well as minimal changes in color and texture compared to microwave cooking."

Carotenoids are known to be sensitive to oxygen, light, and heat. It is estimated that these pigments begin to degrade between 50°C and 60°C, with deterioration dependent on heat treatment duration, plant species, and medium pH [7]. Lipophilic carotenoids, including β-carotene, are particularly affected by thermal processing, impacting visual and organoleptic quality, especially in yellow, orange, and red foods. Carotenoids may also undergo coupled oxidation when lipids are present. Heating β-carotene to 50°C or 100°C for 30 minutes generally shows minimal losses, whereas higher temperatures, such as 150°C, result in significant degradation, particularly of α-carotene.

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Studies on blanching indicate that it preserves 35% of β-carotene in carrot juice or pulp compared to 18% retention in unblanched products [8]. Shorter cooking times, lower temperatures, and reduced water contact have been associated with higher carotenoid retention. However, β-carotene undergoes isomerization during cooking, reducing its biological availability. Carotenoids with all-trans configurations, which are more biologically active, partially convert to cis forms during thermal treatments, diminishing their vitamin potency. Conversely, cooking can enhance β-carotene bio-accessibility by breaking down cell walls and membranes, facilitating nutrient release and absorption [9-11]. Folate, while relatively heat-stable, is sensitive to light, and its degradation can occur due to photodegradation. Despite limited specific studies on folates, they are generally studied in conjunction with other vitamins like vitamin C and B complex, due to their similar properties and association with chlorophyll in green vegetables [12]. This study aims to evaluate the impact of steam and microwave cooking on the concentration of β-carotene in carrots and folates in asparagus, alongside changes in their color and texture.

## Methodology

Asparagus was purchased from a local supermarket in Santiago in 500-gram packages. After cleaning, washing to remove inedible parts, and disinfecting with 50 ppm chlorine for 5 minutes, the asparagus was rinsed and dried to eliminate chlorine residues, following standard protocols to prevent chloramine formation, a carcinogenic compound.

Samples for HPLC analysis were ground and frozen at -18°C until needed. Carrots were also purchased from the local supermarket in 1-kilogram bags, cleaned, washed, and disinfected using the same protocol as for asparagus. The carrots were then cut into uniform sticks (4 cm × 1 cm) for cooking processes, texture measurement, and color analysis using the Computer Vision System (CVS), as illustrated. All experiments were conducted in the kitchen of the Cordon Bleu Culinary School, Faculty of Engineering, Universidad Finis Terrae.

**Determination of microwave and steam thermal treatments:** Table 1 presents the time-temperature conditions for the steam and microwave cooking processes. These conditions were established based on various cooking trials, aiming to minimize undesirable changes in color and texture.

**Table 1:** Method of cooking in carrots and asparagus

| Method of cooking carrots | Steaming/Power | Time (minutes) |
|---|---|---|
| Microwave LG® 100% power | 700 volts | 0-2, 5-5 |
| Steam oven Rational® | 100% steam | 0-2, 5-5 |
| Method of cooking asparagus | Steaming/Power | Time (minutes) |
| Microwave LG® 100% power | 700 volts | 0-4-6 |
| Rational® | 100% steam | 0-8-10 |

## Determination of cooking times

**Steam cooking:** Preliminary laboratory trials identified the optimal steam cooking time for asparagus as ranging from 8 minutes to 10 minutes. At 8 minutes, the asparagus was considered "al dente," while 10 minutes resulted in a cooked product with desirable color and texture (Table 1). Microwave Cooking: Similar findings were observed for microwave cooking. Asparagus achieved an "al dente" texture after 4 minutes of cooking, whereas 6 minutes provided a product with preserved color and texture (Table 1). For carrots, the procedure mirrored that used for asparagus. Carrots were considered "al dente" at 2.5 minutes of both steam and microwave cooking, and optimal color and texture were maintained at 5 minutes (Table 1). The variation in cooking times between asparagus and carrots is likely attributed to differences in dietary fiber content. Asparagus contains an average of 46.9 grams of fiber per 100 grams, while carrots have 19.8 grams per 100 grams of raw product (INTA, 2019). This difference, along with internal water content, may have influenced the cooking times for the two vegetables.

**Determination of vitamins by HPLC:** High Performance Liquid Chromatography (HPLC) was employed to quantify β-carotene and folate levels in carrot and asparagus samples, respectively. Texture and color changes were also assessed using a texture analyzer and colorimeter.

**β-carotene analysis:** The HPLC method followed the protocol described by Hernández and Aldana (2011) [13]:

- 20 grams of carrot sample were weighed into a flat-bottom flask, combined with 70 mL of ethanol, and mixed with a magnetic stirrer under reflux conditions until boiling.
- 20 mL of 50% KOH solution were added for saponification, which was maintained for 30 minutes with moderate agitation.
- The mixture was then rinsed with 50 mL of water in three portions, cooled, and filtered under vacuum.
- The filtered solution was transferred to a 250 mL separating funnel, and 50 mL of hexane were added for extraction. The organic phase was collected after stirring and combined with 0.5 g of ascorbic acid in a round-bottom flask.
- This extraction was repeated nine times. The combined extracts were evaporated to dryness, reconstituted with HPLC-grade methanol, and diluted to 10 mL.
- The final solution was filtered through a 0.2 μm filter

and analyzed using a DIONEX HPLC chromatograph (ULTIMATE 3000 THERMO). The β-carotene standard solution (Sigma) was used to create a calibration curve with six concentrations ranging from 1.0 µg/mL to 10 µg/mL, achieving an $R^2$ value of 0.998. The chromatogram of the β-carotene standard solution at 100 µg/mL, with a wavelength of 453 nm and a retention time of 5.370 minutes.

**Folate analysis:** Folate content was determined using a DIONEX HPLC system (ULTIMATE 3000 THERMO):

- 20 grams of asparagus were homogenized, then mixed with 20 mL of 0.1 M K2HPO4*3H2O, and subjected to rotary evaporation and ultrasonic treatment for 1 hour, followed by centrifugation at 3000 rpm for 25 minutes at 4°C.
- The supernatant was collected, and extraction was repeated. The combined extracts were purified using Solid Phase Extraction (SPE). Folate levels were expressed as µg of Dietary Folate Equivalents (DFE), with calibration performed using folate standards (Sigma 97%) at concentrations ranging from 0.800 to 100 ppm, achieving an $R^2$ of 0.9784. The chromatogram for folate standards at 100 µg/mL, with a wavelength of 290 nm.

## RESULTS

The study revealed significant losses of β-carotene in carrots and folate in asparagus during cooking. Additionally, substantial changes in texture and color were observed compared to the raw vegetables, indicating an impact on sensory quality.

### Statistical analysis

Data analysis will be conducted using Statgraphics Centurion software. ANOVA (Analysis of Variance) will be performed to compare β-carotene and folate contents among samples. The effects of experimental parameters (time and process) on vitamin content, color, and texture will be assessed using ANOVA, followed by the LSD (Least Significant Difference) procedure of the Fisher test. Differences will be considered statistically significant at $p<0.05$. Simple regression analysis will be conducted to explore the relationship between texture and vitamin content across different cooking times, with R as the measure of correlation.

### Effect of steam cooking on β-carotene content

Table 2 presents the variation in β-carotene concentration during steam cooking of carrots compared to microwave cooking. Significant decreases ($p<0.05$) in β-carotene content were observed after 2.5 minutes and 5 minutes of steam cooking, with retention rates of 68% and 60%, respectively. These results highlight the impact of cooking method and duration on vitamin retention. Previous research indicates that thermal processing can both degrade and enhance the bioavailability of carotenoids, depending on the conditions [14-16].

**Table 2:** β-Carotene content in steam and microwave cooking of carrots

| Carrots | Steaming | Microwave |
|---|---|---|
| Time cooking minutes | β-carotene EAR/100 g | β-carotene EAR/100 g |
| 0 | $25^{aA}$, $1^{aA} \pm 0^{aA}$, $21^{aA}$ | $25^{aA}$, $1^{aA} \pm 0^{aA}$, $21^{aA}$ |
| 2, 5 | $18^{bB}$, $2^{bB} \pm 0^{bB}$, $3^{bB}$ | $21^{dD}$, $0^{dD} \pm 0^{dD}$, $31^{dD}$ |
| 5 | $16^{cC}$, $5^{cC} \pm 0^{cC}$, $19^{cC}$ | $17^{eE}$, $5^{eE} \pm 0^{eE}$, $23^{eE}$ |

### Effect of microwave cooking on β-carotene content

Table 2 compares the β-carotene content of carrots cooked in a microwave versus steam cooking. The microwave process showed a less significant decrease ($p<0.05$) in β-carotene content compared to steam cooking. This suggests that microwave cooking is more favorable for short durations. However, prolonged microwave cooking results in higher degradation rates of carotenoids, approaching those observed with steam cooking. Microwave cooking is advantageous for short durations; however, extended cooking times result in greater degradation of carotenoids due to the higher energy of electromagnetic radiation, leading to effects similar to those observed with steam heat.

Means+SD of β-carotene content. Different lowercase letters indicate significant differences between processes (Table 2). Different uppercase letters indicate significant differences within the same process. ($p<0.05$) Fisher's LSD test with 95% confidence level.

### Effect of steam drying on folate content in asparagus

Table 3 shows the folate compounds found in asparagus, expressed as Dietary Folate Equivalents (DFE).

**Table 3:** Folate compounds in asparagus (DFE/100 g)

| Samples | THF | 5-MTHF | 5-FTHF | DFE |
|---|---|---|---|---|
| Asparagus control | U | 150, 2 ± 2, 0 | U | 150, 2 ± 2, 0 |

Folates in foods exist in various forms. Total folates are assessed based on the sum of monoglutamate forms such as Tetrahydrofolate (THF), 5-methyltetrahydrofolate (5-MTHF), and 5-formyltetrahydrofolate (5-FTHF). In the case of asparagus, the

extraction method specifically targets 5-MTHF, which is the most stable and predominant folate form in vegetables, with other forms present in much smaller amounts. This finding aligns with literature that identifies 5-MTHF and tetrahydrofolate as the primary monoglutamate forms in vegetables [17].

Comparing the two cooking methods, it was observed that steam cooking resulted in less folate loss than microwave cooking, despite the longer cooking time required for steaming [18,19]. This difference can be attributed to the impact of electromagnetic waves in microwave cooking, which agitate water molecules and hydrophilic molecules like folates. In contrast, steam cooking appears to better preserve these nutrients. Previous research has noted that frying maintains high stability of water-soluble vitamins; however, it introduces risks related to the formation of toxic compounds such as acrylamide, furans, and harmful glycosylated substances [20]. Furthermore, many studies emphasize optimizing cooking conditions to minimize nutrient loss while preserving sensory attributes such as color and texture [1,21]. Steam cooking is generally regarded as a superior method for preserving nutritional quality compared to direct boiling. Moncada and Gualdrón de Hernández (2006) reported greater vitamin loss with boiling than with steaming [8]. However, it is also evident that extended cooking times, regardless of the method, inevitably lead to some loss of water-soluble vitamins [22].

(Table 4) Means+/-SD of folate content. Lowercase letters indicate significant differences between processes. Different uppercase letters (A, B, C) indicate significant differences within the same process. ($p<0.05$) Fisher's LSD test, 95% confidence level.

**Table 4:** Displays the folate values in asparagus cooked using both methods

| Asparagus | Steaming | Asparagus | Microwave |
|---|---|---|---|
| Time cooking (min) | Folate como EFD/100 g. | Tiempo coccion (min) | Folate como EFD/100 g. |
| 0 | $150^{aA}$, $2^{aA} \pm 2^{aA}$, $0^{aA}$ | 0 | $150^{aA}$, $2^{aA} \pm 2^{aA}$, $0^{aA}$ |
| 8 | $110^{bB}$, $4^{bB} \pm 1^{bB}$, $4^{bB}$ | 4 | $80^{dD}$, $8^{dD} \pm 1^{dD}$, $4^{dD}$ |
| 10 | $77^{cC}$, $8^{cC} \pm 1^{cC}$, $1^{cC}$ | 6 | $58^{eE}$, $3^{eE} \pm 3^{eE}$, $3^{eE}$ |

## Effect of microwave cooking on folate content in asparagus

In the case of asparagus, overcooking in the microwave led to a significant loss ($p<0.05$) of folate over time, with retention varying between 69% and 46% of the initial folate content (EFD). The degradation of folates during microwave cooking was more pronounced compared to the loss of β-carotene observed in carrots. This disparity could be attributed to the prolonged exposure of asparagus to microwave-generated heat and the higher hydrophilicity of folates, making them more susceptible to degradation through interaction with overheated water molecules. Similarly, prolonged steam cooking also reduced the retention of 5-MTHF. Notably, only trace amounts of other folate forms were detected in both raw and cooked asparagus samples. Literature suggests that certain cooking processes can favor folate retention depending on the time and method used [23]. Generally, steam cooking is considered more effective than microwave cooking or immersion in hot water for preserving water-soluble vitamins likes 5-MTHF [24-26]. For instance, Moncada (2006) found that steam cooking retained up to 88% of nutrients when carefully timed [8]. In this study, folate retention ranged between 68% and 60%, with losses directly proportional to cooking time. Microwaving, which heats food by moving water molecules and causing internal cooking, affects water-soluble nutrients like 5-MTHF more than fat-soluble nutrients such as β-carotene. Similar findings were reported by Basulto (2012) for water-soluble vitamins like Vitamin C in broccoli, and folates in celery, asparagus, and other vegetables [22]. While β-carotene decreased by 16% at 2.5 minutes of cooking, the loss increased to about 30% at 5 minutes. King and De Pablo (1987) noted that thermal processes tend to favor the retention of fat-soluble vitamins, particularly β-carotene [27,28]. The optimal cooking method may depend on the volume of preparation, as microwaves may not be ideal for large quantities. The water content of the food, influencing nutrient loss, must also be considered. Kumar and Aalbersberg (2006) found microwaving and steaming to be the least aggressive methods for preserving both sensory and nutritional properties of food [29]. Achon, et al. (2018) emphasized the importance of harmonizing cooking methods for both culinary and health benefits [24].

## Texture analysis for carrots

Texture, alongside color, plays a critical role in consumer preference and selection [1]. Texture analysis was performed using a TA–XT2 Texture Analyzer (Stable Micro Systems, UK) with results processed through Texture Expert 1.2 software and evaluated in Excel. The cutting test utilized an HDP/BS probe. Carrots were cut into 1 cm × 6 cm sticks, and texture was analyzed for raw carrots, as well as those cooked for 2.5 minutes and 5 minutes by steam and microwave. Carrot sticks were cooled to 20°C before measurement. The analysis involved a pre-test speed of 0.1 mm/s and a probe speed of 1.0 mm/s after measurement [30,31].

Carrots exhibit a distinct morphology compared to asparagus, with a pronounced and defined core (xylem) that accumulates carotenoid pigments [32]. The xylem, being harder and more fiber-rich than the phloem, contributes to the irregular resistance

to cutting force in raw carrots. No significant difference was observed in maximum cutting force between xylem and phloem in carrots cooked by either method. However, microwave cooking led to softer tissue and lower resistance to cutting force ($p<0.05$) compared to steam cooking. For asparagus, cuts were made maintaining the cylindrical shape, measuring 6 cm in length, and analyzed post-cooking. Cutting force and specific cutting force were calculated based on the maximum cutting force relative to the diameter of the cut. The same test methodology was applied to both matrices, ensuring consistent calculations for cutting force. The metal blade moved perpendicularly with a 3 mm thick edge on a 75 mm diameter plate.

### Texture analysis of asparagus

Displays the cutting forces for asparagus under steam and microwave cooking conditions. Raw asparagus required approximately 47 Newtons of force for cutting. Significant differences in cutting force ($p<0.05$) were observed across cooking times and methods, with differences being more pronounced than in carrots. Increased cooking time resulted in reduced cutting force required for asparagus, a trend observed more markedly in microwave-cooked samples. The thermal effect of electromagnetic waves likely damages fiber tissues and cell membranes, weakening the food's microstructure. This effect is less pronounced in steam cooking.

### Color analysis by computer vision system

Color analysis using computer vision systems helps assess product quality based on visual appearance, which is crucial for consumer acceptability. The analysis was performed using a D65 halogen light lamp with a 45-degree observation angle. The CIE defined several standardized lighting sources and observation conditions, illuminating the sample at a 45° angle and observing perpendicularly from 45.7 cm away with a 2° viewing angle. The computer vision system utilized Photoshop for color space analysis (RGB, CMYK, CIELab L*, a*, b*), with CIELab used for food research [33-35]. The analysis involves capturing and processing the image, improving quality, applying filters, and quantifying characteristics. The system follows a five-stage process: Image acquisition, processing, segmentation, attribute measurement, and interpretation. Samples were analyzed on a table with a retractable desk lamp holder, using a glass-pressed fluorescent lamp with a parabolic aluminum reflector (PAR38), General Electric brand, 120 V, 60 Hz, 20 W, with a color temperature of Tc=6500°K (D65 daylight simulator).

### Color analysis by computer vision system

The Computer Vision System (CVS) analysis plays a crucial role in evaluating the quality of food based on its visual characteristics, which are vital for consumer acceptance. The CVS setup involved using a Xerox digital paper (150 g/m²), characterized by its smooth texture, high whiteness, and matte finish, positioned 15 cm from the light source. A dark background was employed to enhance the apparent colorfulness of the samples [36]. The camera, a Canon A30, was mounted on a support, and the lighting/observation geometry was set at 45°/0°.

The CVS is an essential tool for color quality control across various food categories, including fruits, vegetables, meats, and canned goods. The color analysis was conducted using the CIELab color space, which provides detailed color coordinates and calculates the total color difference (ΔE*) using the formula:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

where ΔL*, Δa*, and Δb* represent the differences between the measured values and the reference values for each parameter. ΔE* quantifies the magnitude of the total color difference but does not indicate the correctness of the color.

Carrots should ideally display an orange color, characteristic of carotenoids, which may diminish due to oxidation during cooking. Asparagus, on the other hand, should show a green color due to chlorophyll, which can turn dark green through oxidation during thermal processing [37]. To assess the color differences, the L*, a*, and b* values of the samples were recorded at the beginning and end of each thermal process. The color difference was quantified by comparing the samples to a standard reference using the CVS system. The absolute color coordinate differences, as well as the ΔL*, Δa*, Δb*, and total color difference (ΔE), were calculated using the CIE 2000 color difference formula. Table 5 illustrate the variations in L*, a*, b* parameters, and composite modules ΔE, hab*, and C* for carrots cooked by steam and microwave at different times. For raw carrots, significant color variations were observed, mainly due to a decrease in brightness (L* parameter) over cooking time. Additionally, the a* parameter, which indicates red color intensity, showed a decrease, reflecting a shift towards yellow. These changes were consistent across both steam and microwave cooking methods. The ΔE values revealed significant color changes ($p<0.05$) between different treatments and cooking times. A ΔE value greater than 5 denotes a color change perceptible to the human eye, with steam-cooked carrots showing more noticeable color changes at 2.5 minutes. However, at longer cooking times, microwave-cooked carrots exhibited more significant color shifts. The hue angle (hab*) for steam-cooked carrots demonstrated notable variations between red and yellow at 2.5 minutes ($0<hab^*<90$), aligning with the ΔE findings. Conversely, the chroma value (C*), which reflects color purity, sharply declined at 2.5 minutes and 5 minutes, particularly for steam-cooked carrots. This decrease indicates a reduction in the natural hue of the product, which was more pronounced with steam cooking. This finding suggests that the extended exposure of the product's surface to heat in steam cooking results in a more significant loss of carotenoids, leading to more noticeable changes in the vegetable's hue compared to microwave cooking.

Mean ± SD (n=27). Different letters (a, b, c) indicate significant differences in parameters over time ($p<0.05$). Different uppercase letters (X, Y, Z) indicate significant differences within the same

process Table 5.

**Table 5:** Carrots cooked by steam and microwave at different times

| Time (min) | | | | |
|---|---|---|---|---|
| Cooking | Coordenades | 0 | 2, 5 | 5 |
| 0 | L* | $43^{aX}$,$1^{aX}$ ± $4^{aX}$, $5^{aX}$ | $36^{bY}$, $7^{bY}$ ± $7^{bY}$, $2^{bY}$ | $32^{cZ}$, $9^{cZ}$ ± $2^{cZ}$, $6^{cZ}$ |
| 0 | a* | $24^{aX}$, $8^{aX}$ ± $3^{aX}$, $8^{aX}$ | $19^{bY}$, $4^{bY}$ ± $1^{bY}$, $4^{bY}$ | $17^{cZ}$, $3^{cZ}$ ± $5^{cZ}$, $3^{cZ}$ |
| 0 | b* | $28^{aX}$, $1^{aX}$ ± $6^{aX}$, $4^{aX}$ | $19^{bY}$, $0^{bY}$ ± $7^{bY}$, $8^{bY}$ | $17^{cZ}$, $0^{cZ}$ ± $1^{cZ}$, $4^{cZ}$ |
| 0 | L* | $43^{aX}$, $1^{aX}$ ± $4^{aX}$, $5^{aX}$ | $39^{bY}$, $9^{bY}$ ± $5^{bY}$, $7^{bY}$ | $35^{cZ}$, $0^{cZ}$ ± $5^{cZ}$, $4^{cZ}$ |
| 0 | a* | $24^{aX}$, $8^{aX}$ ± 3aX, $8^{aX}$ | $23^{bY}$, $0^{bY}$ ± $1^{bY}$, $9^{bY}$ | $20^{cZ}$, $2^{cZ}$ ± $3^{cZ}$, $3^{cZ}$ |
| 0 | b* | $28^{aX}$,$1^{aX}$ ± $6^{aX}$, $4^{aX}$ | 21bY, 9bY ± 6bY, 1bY | $19^{cZ}$, $3^{cZ}$ ± $1^{cZ}$, $8^{cZ}$ |

Present the variation of the L*, a*, b* parameters and the composite modules ΔE, hab*, and C*, respectively, which were obtained through color analysis by SVC of asparagus samples cooked by steam and microwave at different times. In general, in asparagus, the differences in the color parameters, L*, a*, and b*, were significant with cooking time. Additionally, significant differences were observed between cooking methods. The brightness of asparagus represented by the L* parameter tended to decrease over time, similarly, the green color given by a* shifted to a lower tone but remained within the green range. The values of b*, between a color close to yellow and blue, were less intense as shown in Table 6.

**Table 6:** Changes in color parameters of asparagus according to cooking

| Cooking | Coordinates | 0 minutes | 4 minutes | 6 minutes |
|---|---|---|---|---|
| Microwave | L* | $14^{aA}$, $3^{aA}$ ± $1^{aA}$, $5^{aA}$ | $13^{bA}$, $3^{bA}$ ± $2^{bA}$, $4^{bA}$ | $9^{cA}$, $8^{cA}$ ± $3^{cA}$, $1^{cA}$ |
| | a* | -$25^{aA}$, $6^{aA}$ ± $4^{aA}$, $1^{aA}$ | -$28^{bB}$, $9^{bB}$ ± $4^{bB}$, $0^{bB}$ | -$34^{cB}$, $6^{cB}$ ± $6^{cB}$, $3^{cB}$ |
| | b* | $19^{aA}$, $4^{aA}$ ± $4^{aA}$, $0^{aA}$ | $12^{bC}$, $8^{bC}$ ± $2^{bC}$, $3^{bC}$ | $9^{cC}$, $5^{cC}$ ± $6^{cC}$, $9^{cC}$ |
| **Cooking** | **Coordinates** | **0 minutes** | **8 minutes** | **10 minutes** |
| Steam | L* | $14^{aA}$, $3^{aA}$ +/-$1^{aA}$, $5^{aA}$ | $12^{bB}$, $1^{bB}$ +/-$4^{bB}$, $2^{bB}$ | $8^{cB}$, $3^{cB}$ +/-$2^{cB}$, $6^{cB}$ |
| | a* | -$25^{aA}$, $6^{aA}$ +/-$4^{aA}$, $1^{aA}$ | -$31^{bC}$, $4^{bC}$ +/-$11^{bC}$, $02^{bC}$ | -$41^{cC}$, $2^{cC}$ +/-$6^{cC}$, $9^{cC}$ |
| | b* | $19^{aA}$, $4^{aA}$ +/-$4^{aA}$, $0^{aA}$ | $13^{bD}$, $6^{bD}$ +/-$5^{bD}$, $2^{bD}$ | $11^{cD}$, $9^{cD}$ +/-$1^{cD}$, $1^{cD}$ |

Table 6. Average+SD (n=27). Different letters (a, b, c) indicate significant differences in parameters over time ($p<0.05$). Capital letters (A, B, C) indicate significant differences between treatments.

## Color analysis by computer vision system

The evaluation of ΔE* indicated significant color hue differences ($p<0.05$) across cooking methods. Both microwave and steam cooking exhibited a noticeable decrease in color intensity, with the effect being more pronounced in microwave-treated samples at shorter cooking times (4 minutes and 6 minutes) and in steam-treated samples at longer durations (8 minutes and 10 minutes). This trend corresponds with the observed loss of texture and folates. Color changes are likely linked to pigment degradation, such as chlorophyll, and the disruption of plant tissues [38]. Previous studies also highlight that extended cooking times result in more significant color loss [8,39].

In terms of hue angle (hab*), microwave-cooked asparagus displayed relatively constant values between green and yellow [40-45]. In contrast, steam-cooked asparagus showed a more significant shift towards yellow and red (hab*<90), indicating a greater loss of green color and increased browning due to chlorophyll degradation. Additionally, color purity, as measured by C*, was notably reduced in steam-cooked samples compared to microwave-cooked samples.

## Relationship between texture loss and vitamin loss

The relationship between texture loss and β-carotene retention in carrots revealed a significant correlation (r=0.8138) with considerable variability in texture loss, as depicted. Similarly, for asparagus cooked by steaming, there was a strong correlation between texture loss and folate loss (r=0.9335). Although there was greater variability, the high r value indicates a robust correlation, influenced by compensation between groups of lower values [46-50]. Statistical analysis showed a correlation between texture loss and vitamin loss for both cooking methods and their respective cooking times. The correlation was stronger in asparagus compared to carrots, with a narrower dispersion in asparagus data. Both matrices demonstrated that as vitamin content decreased, texture deterioration also increased, with losses proportional to cooking time [51-61]. The carrot and asparagus cooking processes both revealed significant differences in vitamin content between raw and cooked products across various cooking times. As cooking time increased, vitamin

content decreased proportionally.

## CONCLUSION

Microwave cooking better preserves β-carotene, a liposoluble nutrient, compared to steam cooking. However, steam cooking is more effective in preserving folate (5-MTHF), a hydrophilic nutrient present in asparagus. When selecting a cooking method, factors such as the hydrophilic or liposoluble nature of the nutrients, cooking time, water content, and fiber content should be considered. In terms of texture preservation, steam cooking was less damaging than microwave cooking. Both methods led to significant changes in food color, though steam cooking resulted in less color degradation compared to microwave cooking. A positive correlation was found between texture loss and vitamin loss in the studied foods. As cooking time increased, both texture and vitamin content deteriorated. These findings partially support the hypothesis that nutrient loss due to steam cooking is generally lower than that from microwave cooking, although some evaluations did not show significant differences. Nevertheless, steam cooking, when carefully controlled, generally results in less loss of β-carotene in carrots and folates in asparagus, as well as less impact on color and texture compared to microwave cooking.

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## COMPETING INTEREST

The authors declare that they have no competing interests.

## REFERENCES

1. Mathias-rettig K, Ah-hen, K. Color in food is a measurable quality criterion. Color in food as a measurable quality criterion. Agro Sur Food Science. 2014; 42(2):39-48.
2. Diaz G, Elizabeth E. Comparative analysis of the organoleptic properties of dehydrated carrot with and without osmotic pretreatment. University of San Carlos of Guatemala. 2007; 75.
3. Vanaclocha A, Requena J. Food alteration. Food preservation processes. 2003; 35-45.
4. Baile JI. Obese but malnourished: A serious problem in latin america. Rev Med Chil. 2015; 143(10):1361-1362.
5. Murphy EW, Criner PE, Gray BC. Comparisons of methods for calculating retentions of nutrients in cooked foods. J Agric Food Chem. 1975; 23(6):1153-1157.
6. Ratner R. Nutrition and health. Vitamin B deficiency. 2012. 1-5.
7. Bureau S, Mouhoubi S, Touloumet L, Garcia C, Moreau F. Are folates, carotenoids and vitamin C affected by cooking? Four domestic procedures are compared on a large diversity of frozen vegetables. J Food Sci. 2015; 64(2):735-741.
8. Moncada LM, Gualdron de Hernandez L. Nutrient retention in cooking, frying and baking of three energy foods 1. Revista de Investigacion. 2006. 6(2):179-187.
9. Moyano MJ, Melgosa M, Alba J, Hita E, Heredia FJ. Reliability of the bromthymol blue method for color in virgin olive oils. JAOCS. 1999; 76(6):687-692.
10. Pellegrini N, Chiavaro E, Gardana C, Mazzeo T, Contino D, Gallo M, et al. Effect of different cooking methods on color, phytochemical concentration, and antioxidant capacity of raw and frozen brassica vegetables. J Agric Food Chem. 2010; 58(7):4310-4321.
11. Char CD. Carrots (*Daucus carota L.*). Fruit and vegetable phytochemicals: Chemistry and human health, 2nd Edition. 2017; 46:969-78.
12. Cardona SL, Cabrera CG. Study of the photodegradation of folic acid encapsulated in gum arabic and maltodextrin microspheres. Cuban Pharmacy Magazine. 2010; 44(4):443-455.
13. Hernandez TP, Aldana MI, Rodriguez LI. Validation of a method for the determination of β-Carotene in palm oil by HPLC with UV detector. Alimentos Hoy. 2011; 15(15):32-39.
14. Reddy MB, Love M. The impact of food processing on the nutritional quality of vitamins and minerals. Adv Exp Med Biol. 1999; 459:99-106.
15. Hof KHH, West CE, Weststrate JA, Hautvast JG. Dietary factors that affect the bioavailability of carotenoids. J Nutr. 2000; 130(3):503-506.
16. Hassan M, Atiquzzaman M. Effect of heat treatment on the content of total, soluble and insoluble dietary fiber in some legumes. In Latin American Nutrition Archives. 2000; 50(3).
17. Aguirre ML, Castillo C, Roy CL. Emergent challenges in adolescent nutrition. Rev Chil Pediatr. 2010; 81(6):488-497.
18. Hassan M, Atiquzzaman M, Heredia FJ. Stability of carotenoid pigments in foods. In Latin American Nutrition Archives. 2000; 54(2).
19. Yuan G, Sun B, Yuan J, Wang Q. Effects of different cooking methods on health-promoting compounds of broccoli. J Zhejiang Univ Sci B. 2009; 10(8):580-588.
20. Suaterna Hurtado AC (2011). Frying food: Frying oil. Perspectives Human Nutrition. 2011; 11(1):39-53.
21. Cruz MM, Perez RO. The diversity and nutritional quality of foods. September 2013. 2017.
22. Basulto J, Baladia E, Manera M, Miserachs M, Babio N, et al. Nutrient losses through domestic handling of fruits and vegetables. 2012; 1-20.
23. Basulto JA. 5 a day and Spanish foundation of dieticians-

nutritionists FEDN. Loss of vitamins in culinary processes. 2015.

24. Tunon MA, Gonzalez MG, Moreiras GV. Functional harmony criteria between gastronomy and health: The scientific community vision. Nutr Hosp. 2018; 35:75-84.

25. Pandrangi S, LaBorde LF. Retention of folate, carotenoids, and other quality characteristics in commercially packaged fresh spinach. J Food Sci. 2006; 69(9):C702-C707.

26. Mueller HR. The effect of industrial handling on micronutrients. J Nutr Sci Vitaminol (Tokyo). 1990; 36 Suppl 1:S47-S55.

27. King J, Pablo S. Vitamin losses during food processing. Rev Chil Nourish.1987; 5(3):143-52.

28. Jiang H, Liu Z, Wang S. Microwave processing effects and impacts on food components. Crit Rev Food Sci Nutr. 2018; 58(14):2476-2489.

29. Kumar S, Albersberg B. Nutrient retention in foods after earth-oven cooking compared to other forms of domestic cooking: 1. Proximates, carbohydrates and dietary fibre. J Food Compos Anal. 2006; 19(4):302-310.

30. Caballero AD, Dunoyer AT, Bustillo JM, Vergara AC, Guarin RG. Evaluation of the hardness of various foods. Rev Cubana Estomatol. 2018; 55(1):34-41.

31. Guillen S, Bel MJ, Oria R, Salvador ML. Influence of cooking conditions on organoleptic and health-related properties of artichokes, green beans, broccoli and carrots. Food Chem. 2017; 217:209-216.

32. Lopez S. Phytotechnician learning unit: Anatomy of cultivated plants responsible: Autonomous university of the state of Mexico. J Agric Food Chem. 2015; 1-286.

33. Wallace CA, Holyoak L, Powell SC, Dykes FC. HACCP-The difficulty with hazard analysis. Food Control. 2014; 35(1):233-240.

34. Papadakis S, Malek SA, Kamdem RE, Yam K. A versatile and inexpensive technique for measuring color of foods. Food Tech. 2000; 54:48-51.

35. Moyano MJ, Melgosa M, Alba J, Hita E, Heredia FJ. Reliability of the bromthymol blue method for color in virgin olive oils. JAOCS. 1999; 76(6):687-692.

36. Villarreal MB, Gonzalez AN, Guerra CAA, Gonzalez JGB. Influence of the type and time of cooking on the degradation of chlorophyll in vegetables. JRIFST. 2016; 1(1):411-416.

37. Pezoa M. Methodological proposal that allows evaluating the perception of quality perceived by health users. 2010; 1-17.

38. Aguirre ML, Castillo C, Roy CL. Emergent challenges in adolescent nutrition. Rev Chil Pediatr. 2010; 81(6):488-497.

39. Beltran B, Estevez R, Cuadrado C, Jimenez S, Alonso BO. Carotenoid data base to assess dietary intake of carotenes, xanthophyls and vitamin A: Its use in a comparative study of vitamin A nutritional status in young adults. Nutr Hosp. 2012; 27(4):1334-1343.

40. Chandrasekaran S, Ramanathan S, Basak T. Microwave food processing-A review. Int Food Res J. 2012; 52(1):243-261.

41. Crossen EW. Textural, color and sensory attributes of fruits and vegetables dried using electric forced-air and solar dehydrators. 2017.

42. Morcillo AD, Cabrera JM, Tortajada ED, Perez MER. Fundamental principles and applications of microwave heating. Telecoforum. 2004; 1-3.

43. Fernandez C, Garcia M, Tineo Y, Altomare V. Microwave radiation effects on the sensory properties of some meats and marine products. J Eng. 2008; 31:130-150.

44. Fsis U. Microwave ovens and food safety. 2019; 1-6.

45. Granados C, Acevedo D, Cabeza A, Lozano A. Texture profile analysis in pelipita, harton and topocho bananas. Technol Info. 2014; 25(5):35-40.

46. Gustavo A, Mora J. Steam cooking. Academia Madrid Spain. 2007, 1:1-25.

47. Hernandez R, Candelas C, Meza V, Minjares F. Stability of color and carotene concentration in carrots blanched at different temperatures. IUFST. 2010; 1481-1488.

48. ISP, de SQAN. Procedure to determine folates in wheat flour. ChJS. 2008; 1:1-8.

49. Journal S, Basulto J, Monino M, Farran A, Baladia E, Manera M, et al. Kinanthropometric characteristics in adolescent basketball players. J Hum Nutr Diet. 2014; 18(2):100-115.

50. Kahlon TS, Chiu MCM, Chapman MH. Steam cooking significantly improves *in vitro* bile acid binding of collard greens, kale, mustard greens, broccoli, green bell pepper, and cabbage. 2008; 28(6):351-357.

51. Kirschenbilder E, Castagnino AM, Diaz KE, Rosini MB, Falavigna A. Asparagus chain: Fifth year production of different genotypes and postharvest behaviour. Agron Mesoam. 2015; 26(1):99.

52. Li Q, Shi X, Zhao Q, Cui Y, Ouyang J, Xu F. Effect of cooking methods on nutritional quality and volatile compounds of Chinese chestnut (*Castanea mollissima blume*). Food Chem. 2016; 201:80-86.

53. National Institutes of Health (NIH). What is folate? What is it for? Office of Dietary Supplements. 2016; 1-4.

54. Miglio C, Chiavaro E, Visconti A, Fogliano V, Pellegrini N. Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables. J Agric

Food Chem. 2008; 56(1):139-147.

55. Quaglio P, Messi P. Microwave cooking and food safety. Igiene Moderna. 2000; 113(5):379-389.

56. Suarez de Ronderos, M. del Pilar. Folates: Nutrient rediscovered. Costa Rican Medical Act. 2003; 45(1):5-9.

57. Torres JD, Morelo KJG, Correa DA. Analysis of the texture profile in fruits, meat products and cheeses. ReCiTeIA. 2015. 14(2):63-75.

58. Szczesniak AS. Texture is a sensory property. Food Qual. 2002; 13(4):215-225.

59. Xu F, Zheng Y, Yang Z, Cao S, Shao X, Wang H. Domestic cooking methods affect the nutritional quality of red cabbage. Food Chem. 2014; 161:162-167.

60. Isabel Z, Lorena BGCG. Food composition table. In novartis medical nutrition. 2013; 1-154.

61. Zhaoyuan L. China, an ancient culinary treasure proposal for a culinary route through China for European tourists. 2015; 1-51.