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Influence of cooking conditions on organoleptic and health-related properties of artichokes, green beans, broccoli and carrots

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Colour, pigments, total phenolic content and antioxidant activity were investigated in artichokes, green beans, broccoli and carrots cooked under different conditions. Domestic induction hobs with temperature control were used to evaluate the effect of boiling, sous-vide cooking and water immersion cooking at temperatures below 100 °C on the properties of each vegetable. Sous-vide cooking preserved chlorophyll, carotenoids, phenolic content and antioxidant activity to a greater extent than boiling for all of the vegetables tested and retained colour better, as determined by a*. A reduction of only 10–15 °C in the cooking temperature was enough to improve the properties of the samples cooked by water immersion, except for green beans. Artichokes and carrots suffered pronounced losses of antioxidant activity during boiling (17.0 and 9.2% retention, respectively), but the stability of this parameter significantly increased with sous-vide cooking (84.9 and 55.3% retention, respectively).

1. Introduction

Vegetables contribute to a well-balanced and healthy diet. The phytochemicals and vitamins found in fruit and vegetables are associated with reduced risk of cardiovascular diseases, cancer and diabetes. Given the increasing demand for healthy products, there is a growing interest in the effect of cooking on the nutritional value of vegetables. In response to this concern, many studies have evaluated the effect of using different cooking methods (i.e., boiling, pressure-cooking, microwave cooking, baking, gridding, frying and steaming) on the conservation of the nutrients and organoleptic properties of vegetables (Baardseth, Bjerke, Martinsena, & Skredea, 2010; Jiménez-Monreal, García-Diz, Martínez-Tomé, Mariscal, & Murcia, 2009; Lin & Chang, 2005; Roy, Takenaka, Isobe, & Tsushida, 2007; Ruiz-Ojeda & Peñas, 2013; Turkmen, Sari, & Velioglu, 2005; Zhang & Hamauzu, 2004a).

To reduce the losses caused by some of these cooking methods, mainly due to degradation at high temperatures and leaching into cooking water, different cooking techniques have been tried. An example is sous-vide cooking, which differs from traditional cooking mainly in that the product is vacuum-packed and cooked in a sealed plastic bag at lower temperatures. Unlike other products, such as meat, for which the temperature can be reduced to 65–70 °C, sous-vide cooking of vegetables must be performed at temperatures closer to 100 °C. The cell walls of vegetables remain almost intact during sous-vide cooking, but they are softened by dissolution of the structural material that holds the cells together (Sila, Doungla, Smout, Van Loey, & Hendrickx, 2006). This material begins to dissolve at a temperature between 82 and 85 °C. These values therefore constitute the lowest viable temperature for sous-vide cooking of vegetables. Sous-vide cooking conditions prevent the loss of moisture and volatile compounds (Baldwin, 2012), the latter being important for smell and taste, and minimise nutrient losses caused by leaching. Compared to traditional cooking, sous-vide cooking of vegetables also reduces the degradation and oxidation of pigments, such as chlorophyll and carotenoids (Chiavaro et al., 2012). During traditional cooking of green vegetables, bright green colours turn olive green due to the degradation of chlorophyll, caused by the loss of the central magnesium atom (Damodaran, Parkin, & Fennema, 2008). This process is driven by the acidification of the cooking media as a consequence of the rupture of cellular walls by heat, which releases acids from the vegetables (Haisman & Clarke, 1975). By cooking at temperatures lower than 100 °C, the thermal degradation of chlorophyll is diminished. Moreover, vacuum-packing of the vegetables releases air trapped within the cells, altering the refractive index (Hutchings, 1999). This reduces light dispersion while increasing the apparent brightness of green vegetables. In the case of other pigments, such as carotenoids, which are more vulnerable to oxidation and light than to degradation by heat, reduced exposure to oxygen during sous-vide cooking improves their preservation (Chiavaro et al., 2012). In

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addition to this, sous-vide-cooked vegetables retain higher levels of antioxidant activity and antioxidant compounds (total phenols, vitamin C and carotenoids) than samples cooked by immersion in water (Baardseth et al., 2010; Patras, Brunton, & Butler, 2010).

Recently, a new range of induction hobs equipped with infrared sensors has been introduced to the market. The inclusion of a sensor enables measurement of the generated heat, and this information can be used to estimate the temperature of the food during cooking. The electronic control system compares the measured temperature with the selected temperature and regulates the heat supply so that the desired temperature is precisely maintained (±2 °C). In other respects, induction hobs do not differ much from other domestic appliances used daily for cooking. Vegetables can be cooked using the sous-vide method, using a domestic pot as a thermostatic bath, and by direct immersion in water (without vacuum packaging) at a temperature equal to or below 100 °C. The aim of this research was to evaluate three possible alternatives for cooking vegetables in a domestic environment using induction hobs: boiling, water immersion at temperatures below 100 °C and sous-vide cooking. The effect of these cooking methods on the organoleptic and health-related properties of four vegetables, commonly known as artichokes, green beans, broccoli and carrots, was analysed. One of the important objectives was to determine comparable temperatures and cooking times. Given that vegetables cooked domestically are usually consumed immediately after cooking, the criteria for enzymatic deactivation or biological destruction (used in many studies when there is a conservation period) were not applicable. Instead, cooking conditions were established by textural analysis.

2. Materials and methods

2.1. Vegetable materials and sample preparation

Fresh carrots (*Daucus carota* L. cv. Mantesa), green beans (*Phaseolus vulgaris* L. cv. Perona), broccoli (*Brassica oleracea* L. cv. Parthenon) and artichokes (*Cynara scolymus*, L. cv. Blanca de Tudela) were purchased from a local supermarket and stored at 5 °C in a refrigerator under usual domestic conditions (for no longer than two days). All of the vegetables were cleaned under running tap water and then prepared as follows: the carrots were peeled and sliced into discs 30 ± 1 mm in diameter and 10 mm thick; the green beans were topped and tailed and cut into pieces 30 mm in length; the broccoli was cut into florets of ~30 g weight; and the stems and external bracts of the artichokes were removed to obtain a sample with a diameter of ~7 cm. A stainless steel knife was used for cutting the vegetables (Granton, Sheffield, UK).

2.2. Cooking conditions

All samples were cooked using a PIB.67L34E induction hob (Bosch, Germany) equipped with a temperature-control system and a Bra Terminox pan with a diameter of 18 cm (Bra, Valls, Spain) made of 18/10 stainless steel and with a capacity of 1.75 L. For the sous-vide cooking, 250 g of the vegetable (or two artichokes) was packaged in polyamide-polypropylene cooking vacuum bags (80 μm thickness and 200 × 250 mm size) capable of resisting a maximum temperature of 115 °C (Orved, Musile di Piave, Italy). Air was removed from the bags, which were then sealed using an Orved VM12 vacuum-packaging machine (Orved, Italy). The bags were immersed in 1 L of water once the desired temperature was reached. For boiling and cooking at T < 100 °C, the vegetables were immersed in water without vacuum packaging.

The cooking conditions for the four vegetables were as follows:

- Boiling (B): artichokes: 20, 30 and 40 min; carrots: 5, 7, 10 and 20 min; green beans: 15, 20 and 25 min; broccoli: 12, 15 and18 min.
- Cooking at T < 100 °C (C): artichokes: 90 °C/35, 45 and 55 min; carrots: 90 °C/3 min + 85 °C/11, 22 and 33 min; green beans: 100 °C/1 min + 90 °C/25, 30 and 35 min; broccoli: 90 °C/3 min + 85 °C/17, 20 and 23 min.
- Sous-vide cooking (SV): artichokes: 90 °C/35, 45 and 55 min; carrots: 90 °C/3 min + 85 °C/11, 22 and 33 min; green beans: 100 °C/1 min + 90 °C/25, 30 and 35 min; broccoli: 90 °C/3 min + 85 °C/17, 20 and 23 min.

For all of the aforementioned cooking treatments (boiling, cooking at T < 100 °C and sous-vide cooking), the minimum and maximum cooking times were previously established for each vegetable by sensory analysis. The samples were evaluated by a semi-trained panel consisting of 10 people. A descriptive analysis was conducted to evaluate the texture using a numerical scale (0 = very soft to 10 = very hard). Cooking times resulting in values out of the range of 3–7 were rejected.

For the cases of cooking at T < 100 °C and sous-vide cooking, a short period at temperatures higher than those of the main cooking period was needed in order to avoid extending the cooking time, and the experimental conditions were adjusted to reflect domestic use. In addition, the effect of a freezing period before cooking was also studied. Vacuum-packaged carrots (X + SV) were used as follows: blanching at 90 °C/3 min + freezing at −18 °C/48 h + cooking at 85 °C/11, 22 and 33 min. Additionally, in the experiments with artichokes, a sous-vide cooking test at 100 °C /20, 30 and 40 min (SV100) was performed in order to separately evaluate the influence of vacuum and temperature. Analyses for all cooking conditions were performed in triplicate.

2.3. Textural analysis

Textural measurements were performed using a texture meter (TA-XT2i, Stable Micro System, Godalming, England). A compression test was carried out for carrots, using a cylindrical flat-probe (25 mm diameter) and a 30 kg load cell acting at 1 mm s^{-1}. The hardness of carrots was defined at the peak force with 30% strain. For green beans and broccoli, cross-wise cutting tests were performed with a Warner-Blatzler probe and a 5 kg load cell acting at 1 mm s^{-1}. The maximum force was used as a measure of hardness for broccoli and green beans. For artichokes, a cutting test (on artichoke halves with the inner side downward) was performed, similar to that of green beans and broccoli, using a 30 kg load cell at 2 mm s^{-1}. In addition to this, the hardness of the half artichoke heart bracts at maximum peak force was determined by a puncture test using a 1-mm needle probe at 1 mm s^{-1} with a penetration distance of 10 mm at three points of the heart placed with the inner side upward. Ten replicates were carried out for each vegetable and cooking condition.

2.4. Colour measurement

Colourimetric measurements were carried out on 10 samples for each cooking condition using an IS CAS 140 spectroradiometer (Instrument System, Munich, Germany) with a TOP 100 probe and a NIKKOR 200 mm f/4 macro lens. This was controlled by the ISCOLOR software installed on a PC. Reflectance spectra were measured for 5 s on the surface of the samples. The spectra were measured between 400 and 700 nm every 24 ms. From these spectra, CIELab