



## Trabajo Original

Epidemiología y dietética

### Effect of cooking on antioxidant capacity and sensorial quality of minimally processed cauliflower

*Efecto de la cocción sobre la capacidad antioxidante y calidad sensorial de la coliflor mínimamente procesada*

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#### Abstract

The effect of a cooking treatment (boiling in water at 100 °C for 10 min) on antioxidant composition and sensorial quality of cauliflower that has been previously cut, packaged in a modified atmosphere (5.7-2.3% CO<sub>2</sub> and 17.6-19.7% O<sub>2</sub>) and stored at 5 °C for up to 13 days has been studied in comparison with cauliflower at harvest day.

An increase of ascorbic acid (18%), phenolics (74%) and antioxidant activity (21%) has been observed in stored cauliflower. But the cooking treatment has produced a loss of these compounds by leaching. These losses have been greater for stored cauliflower than for the initial one at harvest day (19% and 13% respectively for ascorbic acid and 31% and 28% respectively for phenolics). However, no variations in antioxidant activity by cooking effect were observed at harvest day, while variations were by 16% in stored cauliflower.

As a result, the antioxidant activity of stored and cooked cauliflower became similar to that of the fresh cauliflower at harvest day.

The storage of cauliflower has produced some changes of color (an increase in b\* parameter from 19 to 20.9) and texture (an increase in shear force from 1948 N to 2375 N). The sensorial acceptability for color and taste of cooked stored cauliflower has been lower than that of the cooked cauliflower at harvest day, but inside acceptable levels. However, the increase in hardness in raw stored cauliflower was not detected by judges in cooked cauliflower. A small incidence of molds on stored cauliflower at 13 days has been observed, thus a washing treatment is recommended.

#### Key words:

Ascorbic acid.  
Antioxidant activity.  
Cooking. Modified atmosphere.  
Sensorial quality.

#### Resumen

Se ha estudiado el efecto de la cocción en agua sobre la capacidad antioxidante y calidad sensorial de coliflor que previamente ha sido cortada, envasada en atmósfera modificada (5,7-2,3% de CO<sub>2</sub> y 17,6-19,7% de O<sub>2</sub>) y almacenada a 5 °C durante 13 días, comparándola con la coliflor recién recolectada.

Se ha observado un aumento de ácido ascórbico (18%), polifenoles (74%) y actividad antioxidante (21%) en la coliflor almacenada cruda. La cocción produjo pérdidas de estos compuestos por lixiviación, que fueron mayores en la coliflor almacenada respecto a la inicial (19% y 13% respectivamente para el ácido ascórbico y 31% y 28% respectivamente para los polifenoles. Sin embargo, no se observaron variaciones en la actividad antioxidante de la coliflor inicial cocida respecto a la coliflor inicial fresca, mientras que en la coliflor almacenada dicha variación fue del 16%.

Como resultado, la actividad antioxidante de la coliflor almacenada y cocida ha resultado similar a la de la coliflor inicial fresca.

El almacenamiento produjo pequeños cambios en color (un aumento del parámetro b\* de 19 a 20,9) y de la textura (un aumento de la fuerza de cizallamiento de 1948 N a 2375 N). La valoración sensorial del color y sabor de la coliflor cocida almacenada fue inferior al de la coliflor cocida inicial, pero dentro de niveles aceptables. El aumento de la dureza en la coliflor fresca almacenada no fue detectado por el panel de catadores en la coliflor cocida. Se observó una ligera incidencia de mohos en la coliflor almacenada 13 días, por lo que se recomienda realizar un tratamiento de lavado.

#### Palabras clave:

Ácido ascórbico.  
Capacidad antioxidante.  
Cocción. Atmósfera modificada. Calidad sensorial.

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## INTRODUCTION

Cauliflower belongs to the genera *Brassicaceae* and it is habitually consumed in Spain, since their production covers most part of the year. Nowadays, there is a consumer demand for fresh products that are ready to use. In this way, cauliflower can be marketed as a minimally processed vegetable, cut in florets, packed and kept under refrigeration until purchased. Cauliflower is ready for boiling as it is usually consumed this way. Minimally processed vegetables are defined as products that undergo some industrial processing such as peeling, cutting and packaging while maintaining their original characteristics.

Nowadays the consumption of diets rich in antioxidant compounds is promoted as an effective way to keep healthy. Several epidemiological studies have indicated that a high intake of plant products is associated with a reduced risk of some chronic diseases, such as atherosclerosis and cancer (Gosslau and Chen 2004, Gundgaard et al. 2003, Linnewiel et al. 2015). These beneficial effects have been partly attributed to compounds with antioxidant activity. The major antioxidants of vegetables are vitamins C and E, carotenoids and phenolic compounds, especially flavonoids. Cauliflower has a high content of vitamin C, mainly in ascorbic acid form, and also polyphenols mainly as flavonoids (Podsdek 2007). It is of interest to know the effect of the processes that are applied to products in the content of these compounds. The effect of different cooking treatments on the content of these compounds has been determined in cauliflower and other brassicas at harvest (Wachtel-Galar et al. 2008). Other authors have evaluated the effect of scalding and freezing storage on these compounds (Puupponen-Piimä et al. 2003). The effect of cooking on the composition of cauliflower minimally processed and stored compared with cauliflower after harvest has not been studied.

High quality cauliflower is white to cream in color, without yellowing or browning caused by sun exposure. Other desirable attributes are good compactness, no mechanical damage and no microbial or fungal attacks (Forney and Toivonen 2004). The effect of packaging in cauliflower cut in florets has been studied in a previous work, in which the atmosphere composition generated using three different packaging films was determined (Simón et al. 2008). In previous studies, changes in sensorial quality and composition in several cauliflower cultivars minimally processed and kept under refrigeration for up to 13 days were evaluated (Simón 2008, Simón et al. 2008). Changes in color and texture were observed during storage. The slight yellowing observed in cauliflower depends on the cultivar and has been considered as acceptable by judges in raw cauliflower. However, Romo-Parada et al. (1989) have reported the presence of strange colorations in cauliflower that have been only detected after cooking. On other hand, the increase in shear force indicates that texture has become tougher. However, the effect of these changes in the quality of cooked cauliflower was not evaluated.

The aim of this study was to evaluate the effect of cooking in water, in habitual conditions of consumption, on the sensorial quality, composition and antioxidant activity of cut cauliflower, packed under the best conditions determined in previous works,

and kept under refrigeration for up to 13 days in comparison with cauliflower at harvest day.

## MATERIAL AND METHODS

### HARVESTING AND PROCESSING OF CAULIFLOWER

Cauliflowers *Brassica oleracea* var. Caprio weighing about 1 kg without leaves were harvested in Navarra (Spain). Inflorescences surrounded by a crown of well-trimmed leaves were selected in order to avoid yellowish color due to sun exposure.

Cauliflowers were cut in florets and placed in polystyrene trays, approximately 450g per tray. The trays were overwrapped with P-Plus film (polypropylene oriented microperforated film) provided by Amcor-flexibles Europe (Gloucester, UK). Permeability of this film for O<sub>2</sub> and CO<sub>2</sub> was about 65000 ml m<sup>-1</sup> day<sup>-1</sup> atm<sup>-1</sup> and water vapor transmission rate was 0.9 g m<sup>-2</sup> day<sup>-1</sup>. The cauliflower packages were stored at 5 °C and 50% relative humidity for up to 13 days, regular conditions in marketing practice.

Cauliflower was not washed with antimicrobials since in previous works the initial mesophiles counts in this vegetable were very low, 2.76 log CFU/g. Moreover, no *Enterobacteriaceae*, coliforms or molds were detected on day 0 (Simón et al. 2008). Only a slight incidence of molds was observed after 20 days of storage at 4 or 8 °C. For this reason, the antimicrobial washing was not considered as necessary in a product of low microbial contamination in the packaging conditions tested.

The determination of gases (CO<sub>2</sub> and O<sub>2</sub>) inside the packages was carried out on days 1, 5 and 13. Samples were taken on days 0 and 13 of storage and the following variables were determined for raw cauliflower: color, texture, sensorial appearance, ascorbic acid content, total polyphenols and antioxidant activity.

Samples of cauliflower were taken on day 0 and 13 for studying the effect of cooking. Four samples of 400 g were boiled in 1 liter of tap water each one, with 1% of sodium chloride added. Cauliflower was introduced to boiling water (100 °C ± 1) and was kept there for 10 min from the reset of boiling. These conditions were previously determined in order to obtain a cooked cauliflower with an integral aspect and ready to eat.

The color was measured in the cooked cauliflower and samples were taken and freeze-dried to determine ascorbic acid, total polyphenols and antioxidant activity. The composition analysis was also carried out in the cooking liquid. The sensorial analysis was also carried out in cooked cauliflower evaluating color, texture and taste.

Four repetitions were carried out in all determinations (4 cauliflowers on day 0 and 4 trays on day 13 of storage, for raw and cooked cauliflower).

### DETERMINATION OF GASES

Carbon dioxide and oxygen were determined using a Checkmate model 9900 O<sub>2</sub> and CO<sub>2</sub> head space gas analyser (PBI-Dan-

sensor. Ringsted, Denmark). Samples were taken automatically with a syringe.

### ASCORBIC ACID CONTENT

Ascorbic acid content was determined after extraction with a metaphosphoric acid solution (5% w/v) using the colorimetric method described by Cakmak and Marschner (1992), where ascorbic acid reacts with 2,2-dipyridyl, giving a rose color whose absorbance was read at 525 nm in a Perkin Elmer model Lambda 10 series UV spectrophotometer (Norwalk, USA).

### TOTAL POLYPHENOLS

Total polyphenols were analysed in an alcoholic extract using the Folin-Ciocalteu method as described by Slinkard and Singleton (1977). Results were expressed as mg of chlorogenic acid/g dry matter.

### ANTIOXIDANT ACTIVITY

Antioxidant activity was determined using the free radical DPPH (Brand-Williams et al. 1995) on the freeze dried extract of cauliflower obtained as described by Pérez-Jiménez et al. (2007). Results were expressed as  $\mu$ moles of Trolox/g dry matter).

### COLOR

Color was determined by measuring L\*, a\* and b\* parameters. L\* parameter measures lightness, ranging between 0 (black) and 100 (white), while a\* and b\* values represent color tone, a\* ranging between positive values (red) and negative values (green) and b\* ranging between positive values (yellow) and negative values (blue) (McGuire 1992). Measurement was done using a HunterLab MiniScan XE colorimeter (Hunterlab, Reston, VA, USA) with an 8-mm diameter diaphragm calibrated with a white tile (X = 81.1, Y = 86.0 and Z = 91.8). Measurement conditions were illuminant C with an observation angle of 10°. In each tray, four determinations were made. The mean was calculated for each tray.

### TEXTURE

Texture was measured using an Instron Universal Testing Machine (Instron Model 1140, Instron Limited, High Wycombe, UK) equipped with a Kramer standard shear cell. Each measurement was taken from 45g of cauliflower placed on the Kramer cell. The shear press displacement speed was 50 mm min<sup>-1</sup> and maximum shear force was measured in Newtons (N). For each tray, two measurements were taken and the mean was calculated.

## SENSORIAL EVALUATION

Ten samples of cooked cauliflower were prepared on days 0 and 13. Samples were evaluated by a panel of 10 judges who were regular consumers of cauliflower, the following parameters were evaluated: color, taste and texture. A structured hedonic scale with numerical scores was used (1: very poor, 2: poor, 3: acceptable, 4: good, 5: excellent). A score of 3 was considered the borderline of acceptability.

## STATISTICAL ANALYSIS

For color in raw and cooked cauliflower, and for texture, the analysis of variance for one factor (storage) with four repetitions was performed. For composition parameters, two factors (storage and cooking) with four repetitions were considered. For sensorial data of cooked cauliflower, one factor (storage) with ten repetitions (ratings of ten judges) was taken into account. Analysis of variance was carried out using SYSTAT for Windows, Statistics version 7.0 (Evanston, Illinois, USA, 1992). The comparison of means was performed using the LSD method for  $p \leq 0.05$ .

## RESULTS AND DISCUSSION

### MODIFIED ATMOSPHERE

The atmospheric composition inside the packages changed throughout storage, reaching levels of CO<sub>2</sub> ranged between 5.7-2.3% and O<sub>2</sub> levels of 17.6-19.7% (Table I). This change during storage has been observed in previous works and it has been related to the decrease in the respiratory activity of cauliflower (Simón et al. 2008, Simón 2008).

O<sub>2</sub> values below 2% caused off odors in cauliflower (Simón 2008). CO<sub>2</sub> levels above 5% cause softening and discoloration of cauliflower when the storage time under these conditions was extended (Romo-Parada et al. 1989). The conditions reached in the present work can be considered as adequate for the cauliflower and no damage of this vegetable was expected.

Taking the results of previous works into account (Simón et al. 2008, Simón 2008), a type of film adequate to the weight of

**Table I.** Atmosphere composition (% of CO<sub>2</sub> and O<sub>2</sub>) inside the packages of minimally processed cauliflower during 13 days of storage at 5 °C

| Day of storage | CO <sub>2</sub> % | O <sub>2</sub> %  |
|----------------|-------------------|-------------------|
| 1              | 5.7 <sup>a</sup>  | 17.6 <sup>c</sup> |
| 5              | 4.0 <sup>b</sup>  | 18.6 <sup>b</sup> |
| 13             | 2.3 <sup>c</sup>  | 19.7 <sup>a</sup> |

Means in the same column with different superscripts<sup>a,b,c</sup> are significantly different ( $p \leq 0.05$ ) for each parameter.

cauliflower packed was selected, since the atmosphere generated was not inadequate for this vegetable. The microperforated polypropylene film selected also prevented the dehydration of the cauliflower due to its low coefficient of water vapor transmission (Simón et al. 2008). Moreover, its antifog treatment has reduced the water condensed inside the film, which was almost not visible.

The modified atmosphere can change among different cauliflower varieties and it can be related to the dry matter content (Simón 2008). The Caprio was the variety that changed the atmosphere least and it is also characterized by a low dry matter content (8.4%) and low compactness (Simón 2008). The Caprio cultivar used in this study had a higher dry matter (9.5%) probably due to the environmental conditions of cultivation. Thus, it may have had a higher capacity to modify the atmosphere than in previous works. In spite of this, the atmosphere reached was not detrimental for cauliflower.

## COMPOSITION OF RAW AND COOKED CAULIFLOWER

A significant increase in both ascorbic acid and total polyphenols (18% and 74% respectively) was observed in stored raw cauliflower compared to the raw cauliflower at harvest day. Consequently, the antioxidant activity also increased (21%) (Table II). The increase of polyphenols after harvest has also been observed in other products such as asparagus (Siomos et al. 2008) or broccoli (Leja et al. 2001). The latter considered the increase in polyphenols as a process related to the postharvest senescence of the product.

Cooking of cauliflower produced a significant decrease in ascorbic acid of 13% and 19% in the cauliflower at harvest day and after storage respectively. Polyphenols were significantly reduced by 28% and 31% in the cauliflower at harvest day and stored cauliflower respectively (Table II). The loss reported in cooked cauliflower by Sikora et al. (2008) was higher (37% for vitamin C and 36% for polyphenols). According to these authors, the treatment time that was 15 minutes, and the portion size of cooked vegetable can influence the loss of these compounds by water cooking.

Higher content of ascorbic acid, polyphenols and antioxidant activity were detected in the cooking water of stored cauliflower than in that of cauliflower at harvest day (Table III). The higher

losses for leaching in stored cauliflower could be explained by the changes produced in the cellular structure during the storage, which could encourage the extraction of these compounds in the cooking water.

In spite of the loss in ascorbic acid and polyphenols observed in cauliflower and in the cooking liquid, the antioxidant activity did not change by the effect of cooking in cauliflower at harvest day, and it has been reduced only by 16% in cauliflower stored for 13 days (Table IV). Wachtel-Galor et al. (2008) found an increase in antioxidant activity in cauliflower by the effect of cooking. This increase was explained by several factors: the presence of new antioxidant compounds due to the thermal treatment or by the changes in cellular structure caused by the cooking and that favor the complete extraction of antioxidant compounds. These possible causes could explain the fact that in the present work no decrease in antioxidant activity was observed or the decrease was lower than expected.

The resulting joint effect of storage and cooking has been that antioxidant activity in cooked stored cauliflower was similar to that of cauliflower at harvest day (Table II).

## COLOR AND APPEARANCE

Changes in cauliflower color caused by storage have been minimal. In raw cauliflower only the increase in  $b^*$  has been significant, representing a slight yellowing of cauliflower (Table IV). These  $b^*$  values have been lower than in previous experiments

**Table III.** Ascorbic acid (mg/l), total polyphenols (mg chlorogenic acid/l) and antioxidant activity ( $\mu$ moles trolox/l) in the cooking water of cauliflower at harvest day and after storage in modified atmosphere at 5 °C during 13 days

|        | Ascorbic acid     | Total polyphenols | Antioxidant activity |
|--------|-------------------|-------------------|----------------------|
| Day 0  | 10.8 <sup>b</sup> | 35.0 <sup>b</sup> | 51.4 <sup>b</sup>    |
| Day 13 | 25.1 <sup>a</sup> | 83.9 <sup>a</sup> | 104.3 <sup>a</sup>   |

Means in the same column with different superscripts<sup>a,b,c</sup> are significantly different ( $p \leq 0.05$ ) for each parameter.

**Table II.** Ascorbic acid (mg/g dry matter), total polyphenols (mg chlorogenic acid/g dry matter) and antioxidant activity ( $\mu$ moles trolox/g dry matter) of raw and cooked cauliflower at harvest day and after storage in modified atmosphere at 5 °C during 13 days

|        | Treatment | Ascorbic acid     | Total polyphenols | Antioxidant activity |
|--------|-----------|-------------------|-------------------|----------------------|
| Day 0  | Raw       | 4.4 <sup>bc</sup> | 5.0 <sup>c</sup>  | 25.9 <sup>b</sup>    |
|        | Cooked    | 3.8 <sup>d</sup>  | 3.6 <sup>d</sup>  | 25.8 <sup>b</sup>    |
| Day 13 | Raw       | 5.2 <sup>a</sup>  | 8.7 <sup>a</sup>  | 31.4 <sup>a</sup>    |
|        | Cooked    | 4.2 <sup>cd</sup> | 6.0 <sup>b</sup>  | 26.3 <sup>b</sup>    |

Means in the same column with different superscripts<sup>a,b,c</sup> are significantly different ( $p \leq 0.05$ ) for each parameter.

with the same cultivar (Simón 2008), where a more yellowish coloration in cauliflower was observed after storage in similar conditions.

No differences in color of cooked cauliflower were observed between the cauliflower at harvest day and the stored cauliflower (Table IV). No strange colorations were observed, since the storage conditions tested (atmosphere and temperature) kept the cauliflower color.

A negative effect in stored cauliflower was observed, since a slight incidence of molds in most of the trays was observed on day 13. This negative effect was not observed in previous works in cauliflower (Simón et al. 2008, Simón 2008). The modified atmosphere generated could not inhibit the growth of molds. This may have been caused by the high humidity reached with the film (Simón et al. 2008). In order to avoid the growth of molds, it is recommended to wash the cauliflower with a suitable antimicrobial before packaging.

## TEXTURE

The shear force increased significantly ( $p \leq 0.05$ ), from 1948 N on day 0 to 2375 N on day 13 of storage. This increase in shear force is related to a change toward a less tender texture and it has also been observed in previous works (Simón et al. 2008, Simón 2008). The shear force values observed for the Caprio cultivar were lower on day 0 and 13 than those reported by Simón (2008) for the same cultivar in similar conditions.

The Caprio cultivar used in the present work has shown higher quality than the one used by Simón (2008), regarding aspects such as dry matter, higher compactness, lower yellowing and a more tender texture. This shows that these quality characteristics depend mainly on the conditions of production.

## SENSORIAL ANALYSIS OF COOKED CAULIFLOWER

Sensorial analysis has shown a value above 4 (good) for color, taste and texture of cooked cauliflower on day 0 (Table V). These values significantly decrease in color and taste for stored cooked cauliflower.

**Table IV.** Color parameters ( $L^*$ ,  $a^*$  and  $b^*$ ) of raw and cooked cauliflower at harvest day and after storage in modified atmosphere at 5 °C during 13 days

| Days | Raw cauliflower   |                    |                   | Cooked cauliflower |                   |                   |
|------|-------------------|--------------------|-------------------|--------------------|-------------------|-------------------|
|      | $L^*$             | $a^*$              | $b^*$             | $L^*$              | $a^*$             | $b^*$             |
| 0    | 87.3 <sup>a</sup> | -0.14 <sup>a</sup> | 19.0 <sup>b</sup> | 74.4 <sup>a</sup>  | -3.7 <sup>a</sup> | 13.8 <sup>a</sup> |
| 13   | 86.5 <sup>a</sup> | -0.25 <sup>a</sup> | 20.9 <sup>a</sup> | 74.9 <sup>a</sup>  | -3.8 <sup>a</sup> | 13.6 <sup>a</sup> |

Means in the same column with different superscripts<sup>(a,b,c)</sup> are significantly different ( $p \leq 0.05$ ) for each parameter.

The decrease in color values is not easily explained, since the objective color measurements obtained with a colorimeter had not shown differences (Table IV).

In the case of taste, some judges detected a slightly bitter taste in the stored cauliflower and the values of taste decreased. The increase of polyphenols could be related to the bitter taste since this has been related to some phenolic compounds (Drewnowski 2001). It has also been related to some glucosinolates such as neoglucobrassicine and sinigrine (Engel et al. 2002)

The changes in texture registered by the increase in shear force in raw cauliflower were not significantly detected in cooked cauliflower by judges (Table V).

Nevertheless, the evaluation of the three aspects in stored cauliflower was above 3, which was considered the borderline of acceptability.

**Table V.** Sensory valuation\* of cooked cauliflower at harvest day and after 13 days of storage in modified atmosphere at 5 °C

| Day of storage | Color            | Taste            | Texture          |
|----------------|------------------|------------------|------------------|
| 0              | 4.4 <sup>a</sup> | 4.4 <sup>a</sup> | 4.1 <sup>a</sup> |
| 13             | 3.8 <sup>b</sup> | 3.4 <sup>b</sup> | 3.8 <sup>a</sup> |

\*1: very poor, 2: poor, 3: acceptable, 4: good, 5: excellent; Means in the same column with different superscripts<sup>(a,b,c)</sup> are significantly different ( $p \leq 0.05$ ) for each parameter.

## CONCLUSIONS

The antioxidant compound, ascorbic acid and polyphenols increased during storage, but decreased after cooking due to the leaching in the cooking water. This loss by leaching was higher in stored cauliflower than in the cauliflower at harvest day. As a result of the changes observed the antioxidant activity of cooked stored cauliflower was similar to that of the fresh cauliflower at harvest day.

The storage of cut cauliflower in florets packed in an adequate atmosphere for up to 13 days at 5 °C resulted in minimal changes with regard to color and texture that hardly had any effect in the sensorial evaluation of cooked cauliflower. Stored cooked cauliflower obtained a slightly lower sensorial score than cauliflower at harvest day—mainly in taste—but within acceptable limits.

The main problem observed was the slight incidence of molds in raw cauliflower on day 13 of storage. Therefore, a washing of cauliflower with an antimicrobial before packaging should be recommended in order to prevent the growth of molds.

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