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Induced changes in bioactive compounds of kailan-hybrid broccoli after innovative processing and storage

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ABSTRACT

The glucosinolates, sulforaphane, vitamin C and lutein content after several industrial cooking methods on the new kailan-hybrid broccoli and their changes during storage for 45 days at 4 °C were studied. Boiling and *sous vide* induced the highest glucosinolate loss (80%), while low pressure (LP) steaming, microwaving (MW) and *sous vide*-MW showed the lowest (40%) loss. Glucoraphanin was the most thermostable glucosinolate. Throughout their commercial life, microwaved and grilled samples showed a decrease in total glucosinolates. Generally, myrosinase activity was completely inhibited after cooking with undetected sulforaphane contents. The initial total vitamin C dropped by up to 58% after cooking and progressively decreased during storage, with *sous vide*-MW (92%) and microwaving (21%) showing the highest and lowest decrements, respectively. LP steaming and microwaving were the best industrial cooking methods for maintaining the glucosinolate and vitamin C contents, and enhancing up to 7.5-fold the initial lutein content.

1. Introduction

Healthier diets, safety and convenience are targets correlated by current consumers to high nutritional and sensory quality plant products. In the last few years, innovative and attractive ready-to-use plant products, which satisfy the consumer demand, are appearing. Brassicaceae is a vegetable family that is highly appreciated due to their bioactive compounds and which commonly requires minimum cooking procedures (Manchali, Murthy, & Patil, 2012). However, its specific flavour and sulphur odours led the breeding companies to find new varieties with milder organoleptic characteristics. Recently a natural kailan-hybrid broccoli (*Brassica oleracea* Italica Group × Alboglabra Group), commercially known as Bimi®, Tenderstem®, Vellaverde®, Broccolini®, asparation, inspiration, broccoletti or broccolette, has been developed. This kailan-hybrid has a long slender stem that is completely edible, with a mild sweeter taste and less intense flavour than conventional broccoli cultivars (Martínez-Hernández, Gómez, Artés, & Artés-Hernández, 2011). The kailan-hybrid broccoli is widely consumed in northern European countries, the USA, Brazil and Australia, among others. United Kingdom is among the main consumers of this kailan-hybrid in Europe with 3000 tons commercialized in 2011, 20% more than the

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previous year. In the past 12 months, kailan-hybrid household penetration has experienced a 14% increase and purchase frequency has also increased by over 8% (Fresh Plaza, 2012).

Broccoli is a high-value and seasonal commodity. It is one of the most important vegetables produced in the Mediterranean coastal area of Spain (Artés, Vallejo, & Martínez, 2001). Its commercial interest has increased owed to its considerable relevance as a healthy vegetable, mainly due to its claimed anticancer, antioxidant, anti-inflammatory and cardiovascular diseases preventing properties (Losso & Truax, 2009; Manchali et al., 2012; Mirmiran, Bahadoran, Hosseinpanah, Keyzad, & Azizi, 2012; Yeh & Yen, 2009). This is because broccoli is rich in several health promoting compounds like glucosinolates, vitamins (mainly vitamin C), carotenoids (comprising lutein, the 46–77% over total) and phenolics, among others (Nunn, Giraud, Parkhurst, Hamouz, & Driskell, 2006; Pellegrini et al., 2010; Shahidi & Ho, 2003; Traka & Mithen, 2009). Tissue disruption, such as that caused by chewing or cutting, allows glucosinolates to come into contact with myrosinase (β-thioglucoside glucohydrolase EC 3.2.3.1), which causes rapid hydrolysis to form glucose and a range of intermediates, such as isothiocyanates, thiocyanates and nitriles (Jones, Frisina, Winkler, Imsic, & Tomkins, 2010). Glucoraphanin, the main glucosinolate found in broccoli, forms the isothiocyanate sulforaphane (1-isothiocyanato-4-methylsulphinylbutane), depending on reducing conditions (such as acidic pH, ferrous ions, ascorbate) and/or the action of the epithiospecifier protein (ESP) the sulforaphane nitrile, which has less potent effect on Phase I and II enzymes than sulforaphane nitrile (Jones et al., 2010).

The ready meals segment is an increasing sector in the fifth range industry. In Spain, the vegetables-based ready meals registered a consumption of 1.08 kg capita^{-1} year^{-1}. From these vegetables-based ready meals, the sautéed (stir frying) dishes represent 30.1% over the total turnover (Sainz, Fálder, Vera, & Martín-Cerdeño, 2008).

The effects of cooking by boiling, LP and high pressure (HP) steaming and microwaving treatments on the aforementioned bioactive compounds content and on their bioavailability have been reported in conventional broccoli cvs. (Galgano, Favati, Caruso, Pietrafesa, & Natella, 2007; Jones et al., 2010; Miglio, Chiavaro, Visconti, Fogliano, & Pellegrini, 2008; Petersen, 1993; Zhang & Hamauzu, 2004). Nevertheless, these studies focused on cooking methods as domestic processes with no information about industrial cooking treatments, which involve an additional step of chilled storage for several weeks. Furthermore, to the best of our knowledge, no studies on the effects of *sous vide*, *sous vide*-microwaving (*sous vide*-MW) and grilling on glucosinolate, endogenous sulforaphane, vitamin C and lutein contents of broccoli have been reported yet, neither have their changes throughout the subsequent commercial chilled storage. In addition, most of these works studied the cooking effects on glucosinolate, but very limited information exists about the isothiocyanate levels, particularly sulforaphane, which is the biologically active form in humans.

The aim of the current work was to identify the bioactive compounds changes (glucosinolate, sulforaphane, vitamin C and lutein) on the new kailan-hybrid broccoli after the innovative *sous vide*, *sous vide*-MW and grilling, compared to those of conventional cooking methods. These induced changes of the health-promoting compounds were studied after industrial treatments and throughout the subsequent chilling storage.

2. Material and methods

2.1. Plant material

Kailan-hybrid broccoli (*Brassica oleracea* Italica Group × Alboglabra Group) of 15–18 cm long (Martínez-Hernández, Artés-Hernández, Gómez, & Artés, 2013) was hand-harvested in March in open air cultivation parcels of the Campo de Lorca S.C.L. farm (Lorca, Murcia). Broccoli was grown according to integrated pest management cultural practices. Immediately after harvesting, broccoli was crushed ice pre-cooled and transported by car about 90 km to the Pilot Plant of the Universidad Politécnica de Cartagena, where it was stored at 1 °C and 90–95% RH.

2.2. Samples preparation and cooking treatments

Minimal processing was accomplished on the following day in a disinfected cold (8 °C) room. Broccoli was carefully inspected, selecting those free from defects and with a similar visual appearance. The plant material was cut in about 15-cm-long spears and leaves were eliminated using a sharp knife. Then, the cut broccoli was washed with chilled chlorinated water (2 min; 5 °C; 100 mg L^{-1} NaClO; pH 6.5) and rinsed with chilled tap water (1 min; 5 °C). The following seven industrial cooking treatments were applied to the sanitised plant material (hereinafter called ‘raw’):

- *Boiling:* broccoli was boiled in an open pot (25 L capacity) with boiling water (100 °C) for 3.5 min. The broccoli weight/cooking water volume rate (*w*/*v*) was 5/15.
- *LP steaming:* broccoli was treated for 5 min with water vapour at 100 °C in an industrial autoclave with the pressure valve opened in order to cook at low pressure steaming (0.02 MPa).
- *HP steaming:* the kailan-hybrid was placed on several layers of a steel stainless basket and steam cooked (2 min) in the industrial autoclave (0.1 MPa pressure).
- *Sous vide:* around 175 ± 5 g broccoli was placed within sterile vacuum polypropylene (PP) bags (20 × 25 cm) and vacuum-packaged (−98.2 kPa) with a vacuum chamber (V821, Sammic, Guipúzcua, Spain). After packaging, vacuum-packaged broccoli was placed on different layers of a stainless steel basket. When the autoclave cooking water reached 90 °C the basket was submerged for 15 min. After cooking, the *sous vide* broccoli was rapidly cooled down to about 20 °C in a water–ice bath (0 °C).
- *Microwaving:* about 130 g broccoli was placed inside sterile PP special vacuum bags and treated for 2.5 min in an industrial microwave (MWB-17AE, Fagor Industrial, Valencia, Spain) at 900 W. After microwaving, PP bags were sealed under N_2 atmosphere using the above-mentioned vacuum chamber.