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Influence of blanching and low temperature preservation strategies on antioxidant activity and phytochemical content of carrots, green beans and broccoli

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Work dedicated to my grand parents

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ABSTRACT

The objective of this study was to investigate the effect of blast freezing and blanching in combination followed by chilling, on the antioxidant activity (ARP), phenols, ascorbic acid and colour of broccoli, carrots and green beans. No significant changes ($p > 0.05$) in ARP of blanched frozen (BLFR) broccoli, carrot and green beans were observed. In contrast, UBFR (unblanched frozen) treatments caused a significant decrease ($p < 0.05$) in ARP and ascorbic acid content of vegetable samples. BLFR treated samples had better retention of antioxidant activity and ascorbic acid as compared to UBLR counterparts at chill storage (4 °C) for 7 days. However, no significant changes were observed in phenol content for all vegetables. Ascorbic acid decreased exponentially for both blanched and unblanched samples. The reaction rate constant (k) increased from 1.06×10^{-1} day^{-1} to 1.17×10^{-1} day^{-1} for blanched and unblanched broccoli florets and from 4.6×10^{-3} day^{-1} to 1.98×10^{-1} day^{-1} for blanched and unblanched carrots during 7 days storage. Result presented here indicates greater stability of nutritional parameters for BLFR samples compared to UBFR samples during 7 days storage at 4 °C for all vegetables.

1. Introduction

Fruits and vegetables contain range of phytochemicals, in addition to well-known antioxidants, such as vitamins C and E, or polyphenols, which significantly contribute to their total antioxidant activity (Cao, Sofic, & Prior, 1996; Prior et al., 1998). Epidemiological and clinical investigations have associated diets rich in fruits and vegetables with reduced risk of heart, cardiovascular, neurological and chronic diseases, and various forms of cancer (Ames, Shigenaga, & Hagen, 1993). Due to the seasonal and perishable nature, raw vegetables are subjected to some form of preservation in order to make them available for later consumption (Lin & Brewer, 2005). Freezing of fruits and vegetables is generally regarded as superior to other food preservation techniques such as canning and dehydration, with respect to retention in sensory attributes and nutritive properties. Freezing is often employed to maintain fresh-like characteristics with minimal loss of nutrients such as vitamins, and antioxidant content over long periods (Prochaska, Nguyen, Donat, & Piekutowski, 2000). However, while freezing on its own helps to preserve food through the slowing of enzymatic reactions, senescence and microbial growth; it does not fully stop these processes (Bahceci, Serpen, Gokmen, & Acar, 2005). The result can be the development of off-odours, off-colours, off-flavours, changes in texture and nutrient loss. Fruits and vegetables are blanched prior to freezing mainly to inactivate enzymes, reduce microbial load, remove gases from the plant tissue, cause shrinkage of the product to facilitate packaging, fix texture, colour, and clean the surface of the vegetable (Bahceci et al. 2005; Barrett & Theerakulkait, 1995).

Typically, blanching is carried out by treating the vegetables with steam or hot water for 1–10 min at 75–95 °C, the time/temperature combination depending on the type of vegetable (Cano, 1996). Blanching of foods involves mild heating in water and serves. Blanching can have negative effect on nutrients such, as vitamins and phenolic compounds which are relatively unstable when subjected to heat treatments (Prochaska et al., 2000). Apart from processing, storage conditions and domestic cooking and preparation have significant effect on phytochemicals such as ascorbic acid and phenols (Patras, Brunton , Tiwari, & Butler.,2009a; Rawson, Koidis, Patras, Tuohy,& Brunton, 2010; Vallejo, Tomás-Barberán, García-Viguera, 2002; Verkerk & Dekker, 2004).

Consumers are now becoming aware of the need to consume a variety of fresh vegetables to maximise their intake of beneficial

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antioxidants (Prochaska et al., 2000). Several studies show the effects of freezing on green peas and spinach, carrots, broccoli, green beans (Howard, Wong, Perry, & Klein, 1999; Korus, Lisiewska, & Kmiecik, 2002; Murcia, López-Ayerra, Martinez-Tomé, Vera, & García-Carmona, 2000; Saccani et al., 2001). In addition, freezing has, in some studies, been shown to influence the quality and nutritive value of foods (Srinivasan, Xiong, & Blanchard, 1997). There is very little information on how these processes in combination influence the quality and nutritive value of foods despite the fact that they are commonly used together to prolong shelf life.

Although freezing is an effective method of preserving foods some deterioration in frozen food quality occurs during storage. Therefore the objective of the current study was to examine the effect of blast freezing and blanching in combination followed by chilling, on the ARP, phenols, ascorbic acid and colour of broccoli, carrots and green beans with a view to their use as components of ready-meals.

2. Materials and methods

2.1. Vegetable material and sample preparation

Fresh carrots (*Daucus carota* L. cv. Nairobi), green beans (*Phaseolus vulgaris* L cv. Emerit) and broccoli (*Brassica oleracea* L cv. Monaco) were purchased from a local supplier (Donnelly's Ltd., Dublin, Ireland). The carrots were washed, peeled (using a hand held domestic peeler) and sliced into discs of 5 mm thickness using a mechanical slicer (Berkel Ltd, Ontario, Canada). The green beans were washed, topped and tailed. Broccoli was separated into florets and leaves and inedible stems were removed.

2.2. Blanching and blast freezing experiment

Two different pre-treatments were used in this trial. Carrot, green beans and broccoli were equally divided (200 g each) into two batches [Batch A and Batch B]. Batch A was subjected to blanching (BL), whereas no blanching treatments (UB) were given to the batch B. Blanching was carried out by placing samples in water at 95 °C for 3 min. The proportion of water to the raw material used was 5:1 by weight. Following this, samples were cooled in distilled in water for 2–3 min. Prior to blast freezing, samples (200 ± 1 g) were vacuum-sealed in 20 cm × 30 cm in Polypropylene pouches (thickness- 75 μm, gas permeability- 2.7 g m^{-2} d, sealing temperature- 100–180 °C, Packex Industries Ltd., Wicklow, Ireland using Vac-star S220 vacuum sealer (Vicquip Ltd., Dublin, Ireland)). The blanched and unblanched vegetables were blast frozen at −30 °C for 2.5 h (Nu-Avon, Wiltshire, England; air speed 3.8 m s^{-1}) (Fig. 1).

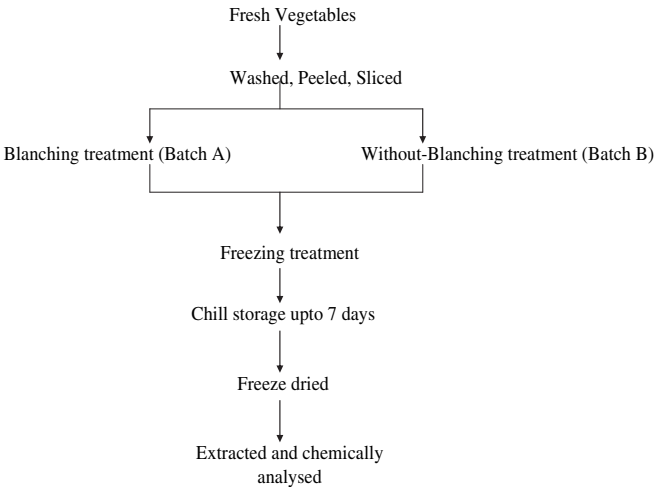

Fig. 1. Overview of the steps involved in blanching, freezing and chill storage treatments.

2.3. Chill storage

Blanched frozen [BLFR] and unblanched frozen [UBFR] samples were placed in different propylene pouches and stored in air at 4 °C for 0, 3, 5, 7 days. Each treatment was replicated three times. At each sampling point, samples were removed; freeze dried (Frozen in Time Ltd., York, UK) at a temperature and pressure of −50 °C and 0.03 mbar respectively for more than two days and tested for antioxidant indices and instrumental colour.

2.4. Measurement of total antioxidant activity

Methanolic extracts were prepared by adding 25 mL of HPLC grade methanol to 1.25 g of freeze dried powder. Samples were then homogenised for 1 min at 24,000 rpm using an Ultra-Turrax T-25 Tissue homogenizer (Janke & Kunkel, IKA®-Labortechnik, Saufen, Germany). DT20 tube with a rotor stator element with a dispersing element was utilized. The stator diameter was 19 mm and rotor diameter of 12.7 mm with gap between rotor and stator of 0.3 mm with shaft length of 19.2 cm was used. The samples were then vortexed with a V400 Multitude Vortexer (Alpha laboratories, North York, Canada) for 20 min at 800 g and centrifuged for 15 min at 2000 g (MSE Mistral 3000i, Sanyo Gallenkamp, Leicestershire, UK). 10 mL of the sample was filtered through PVDF Acrodisc syringe filters (pore size 0.45 μm, Sigma, Ireland,) and stored at −20 °C for subsequent analysis. Total antioxidant activity was measured using the DPPH assay as described by Goupy, Hugues, Boivin, and Amiol (1999). Briefly 500 μL of diluted sample and 500 μL of the DPPH (0.238 mg/mL^{-1}) working solution were mixed in a microcentrifuge tube. After vortexing, the tubes were left in the dark for 30 min at room temperature after which the absorbance was measured against methanol at 515 nm using a spectrophotometer (UV-1700 Pharma Spec, Shimadzu, Milton Keynes). The decrease in absorbance of a sample was calculated in comparison to a blank sample (500 μL methanol and 500 μL DPPH). The relative decrease in absorbance (PI) was then calculated as follows: PI (%) = 1 − (Ae/Ab), with Ae = absorbance of sample extract and Ab = absorbance of blank. The PIs used to calculate the related antioxidant activity were superior (PI1) and inferior (PI2) to the value estimated at 50%. Antioxidant activities were expressed as the IC50 i.e. the concentration of antioxidant required to cause a 50% reduction in the original concentration of DPPH. For ease of interpretation, antiradical powers were also calculated and defined as the inverse of the IC50 value Eq. (1) and (2). Finally, the antioxidant activity of the extracts was compared to that of a synthetic antioxidant (Trolox) and expressed as Trolox equivalent antioxidant activity (TEAC) values. The analyses were done in triplicate and all quantitative results are reported on a dry weight basis.

$$\Delta C = \frac{(C_1 - C_2) \times (PI_1 - 50)}{PI_1 - PI_2} \quad (1)$$

$$IC_{50} = C_1 - \Delta C \quad (2)$$

$$ARP = \frac{1}{IC_{50}} \quad (3)$$