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Modelling the effect of different sterilisation treatments on antioxidant activity and colour of carrot slices during storage

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ABSTRACT

The effect of F_0 treatment time (min) and storage on the antioxidant activity and Hunter colour parameters (L^*, a^*, b^*) of carrot slices was investigated. Carrot slices were sterilised for 0 (control), 3, 15 and 50 min and subsequently stored for 0, 3 and 6 months. Significant differences were observed in colour values of carrot slices with no significant difference beyond F_0 treatment of 3 min. Regression modelling was used to investigate the main effects of treatment time and storage. Treatment time and storage period was found to be significant. Predicted models were found to be significant ($p < 0.05$) with low standard error and high coefficients of determination (R^2). This study proposes the predicted models for quality parameters of sterilised carrot slices.

1. Introduction

Carrot (*Daucus carota* L.) is a widely consumed vegetable with high nutritional value as it is an important source of carotene. It can be eaten raw, processed or manufactured into a variety of products including juices, dehydrated soups, baby foods, and can be utilized in many chilled and frozen meals. To prevent unwanted changes during storage, fruit and vegetable products are generally subjected to some type of treatment during processing in order to inactivate enzymes such as polyphenol oxidase (Reid, 1990). In thermal processing of food such as vegetables, heat acts as a medium to develop taste and flavor, and in addition lowers the microbial load (Miri et al., 2008). To produce low-acid (pH > 4.5) ambient stable products using conventional heating technology, standard industrial practice is to apply, as minimum, a thermal process equivalent to 121.1 °C for 3 min at the slowest heating point of the product (cold point) to deliver at least a 12 log reduction of the spores of the pathogen *Clostridium botulinum* (Department of Health., 1994).

Canned foods are a significant component of the diet of most individuals in developed countries, offering food in a convenient form with year-round availability (Pither, 2003). The canning process depends on heat treatment for the destruction of microorganisms and preservation of the food, which is then generally considered to have an indefinite microbiological shelf-life providing that pack integrity is maintained. The degree of thermal processing, in terms of both temperature and duration of the treatment, is dependent upon the chemical and physical composition of the product. Both physical and chemical changes occur during processing and, to a lesser extent, during storage, and it is these that determine the product quality in terms of its sensory properties and nutrient content (Pither, 2003). These physicochemical changes, which can be either desirable or undesirable, are influenced by the time and temperature of the process, the composition and properties of the food, the canning medium, and the conditions of storage (Pither, 2003). Colour is an important quality marker for fresh and processed carrots (Simon, 1985) and colour changes during canning can be brought about by the breakdown of natural pigments, by the production of colours due to oxidation reactions, by the Maillard reaction, and by interactions between product constituents, e.g., metals and polyphenolic compounds (Gomyo & Horikoshi, 1976; Kirigaya, Kato, & Fujimaki, 1968; Pither, 2003).

Carotenoids are fat-soluble, highly unsaturated red, orange, or yellow pigments that are susceptible to oxidation and isomerisation under the conditions of heat and low pH, such as those used during the canning process (Bao & Chang, 1994; Shi & Le Maguer, 2000; Simon & Lindsay, 1983). Leadley, Tucker, and Fryer (2008) studied a small range of thermal processes ($F_0 = 1$ min to $F_0 = 3$ min) to evaluate the colour and texture of green beans but did not find much variations among the samples in terms of colour (L^*, a^*, b^*). It is well-documented that colour and nutrient values are generally important indicators of product 'quality' for consumers and are also the two parameters that are changed by a thermal sterilisation and there is considerable industrial interest in technologies that can deliver ambient shelf stability in low-acid foods (Leadley, Tucker, & Fryer, 2008).

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The objective of this study was to investigate the effect of F_0 treatment on carrot slices during storage and to model the changes in antioxidant activity, phenols, carotenoids and colour parameters.

2. Materials and methods

2.1. Chemicals

2,2-Diphenyl-1-picrylhydrazyl (DPPH), Folin–Ciocalteau reagent (2N), sodium carbonate, gallic acid and L-ascorbic acid were obtained from Sigma Aldrich (Dublin, Ireland). Hexane, acetone, metaphosporic acid and methanol (HPLC grade) were purchased from BDH England (Poole, BH15 1TD).

2.2. Preparation of carrot samples for processing

Fresh carrots (20 kg) (*D. carota*, cv Nairobi) were purchased from a local market (Donnelly's Ltd., Dublin, Ireland) and stored at 4 °C until use within one week. Carrots were washed, cleaned to remove adhering soil and sliced using a Berkel 800 meat slicer (Berkel Company, Indiana, USA) to a uniform thickness of 5 mm. Samples were subjected to blanching (50 °C/30 min, 90 °C/5 min) prior to sterilisation. Hot samples were placed in cans containing 0.75% NaCl in water with 6–10% headspace. Samples were cooled rapidly prior to canning experiment.

2.3. Canning experiment

The prepared cans (75 × 110 mm, WEI/WEISS03, Germany) were loaded into a pilot scale retort (Barriquand Steriflow, Roanne, France). Sample core temperature profiles and F_0 values were recorded during the process, using an Ellab E-Val TM TM9608 data module (Ellab [UK] Ltd., Norfolk, England) connected to a laptop. A standard Ellab SSA-12080-G700-TS temperature probe was inserted through an Ellab GKM-13009-C020 packing gland (20 mm) into a 30 mm think carrot cylinder placed in a can to record the cook cycle. Temperature was monitored every 10 s. The samples were heated to achieve a process equivalent to 121.1 °C for 3, 15 or 50 min at the end of the cook-cool cycle and samples were stored for 0, 3 and 6 months at room temperature. Prior to any canning experiment, all Ellab unit probes were calibrated against a JOFRA (ATC-155B) calibration unit at temperatures of 115, 121.1 and 125 °C and all results associated with the calibration did not exceed ±0.1 °C. A typical time temperature profile for sterilisation is shown in Fig. 1.

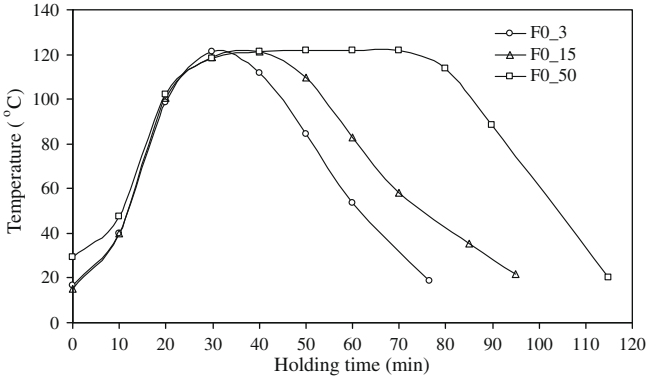

Fig. 1. Typical retort temperature profile for sterilised carrot slices.

2.4. Measurement of total antioxidant capacity and phenolic content

Methanolic extracts were prepared by adding 25 ml of HPLC grade methanol to 1.25 g of freeze dried powder and homogenising for 1 min at 24,000 rpm using an Ultra-Turrax T-25 tissue homogenizer (Janke and Kunkel, IKA®-Labortechnik, Saufen, Germany). The samples were vortexed with a V400 Multitude Vortexer (Alpha laboratories, North York, Canada) for 20 min at 1050 rpm and centrifuged for 15 min at 2000*g* (MSE Mistral 3000i, Sanyo Gallenkamp, Leicestershire, UK). Ten millilitres 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 capacity was measured using the DPPH assay as described by Goupy, Hugues, Boivin, and Amiol (1999). Five-hundred millilitres of diluted sample and 500 μl of the DPPH (0.238 mg/ml) working solution were added to 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 spectrophotometre (UV-1700 Pharma Spec, Shimadzu, Milton Keynes). Antioxidant activities were expressed as the IC_{50}, i.e., the concentration of antioxidant required to cause of 50% reduction in the original concentration of DPPH. For ease of interpretation antiradical powers were also calculated and defined as the inverse of the IC_{50} value. Finally the antioxidant capacity of the extracts were compared to that of a synthetic antioxidant

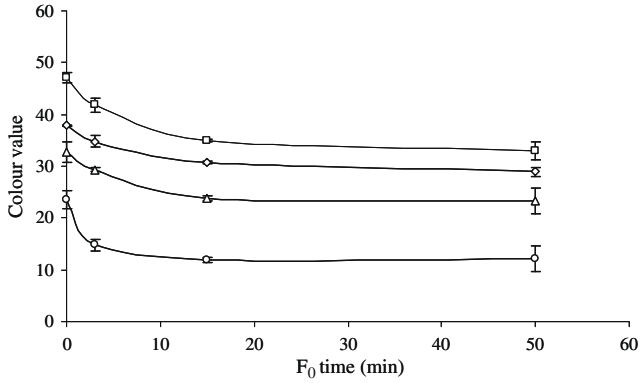

Fig. 2. Changes in hunter colour values (□) L^*, (◇) whiteness, (△) chroma and (○) a^* during F_0 treatment time (min).

Table 1
Influence of different sterilisation treatments on quality parameters of carrot slices.

Treatments	ARP	Phenols	Carotenoid	L^*	a^*	b^*	TCD	Chroma	Hue	Whiteness
Control	0.28^{ab}	173.77^{c}	99.21^{b}	46.96^{a}	22.57^{a}	22.55^{b}	0.00^{c}	31.91^{a}	44.96^{c}	38.10^{a}
$F_0$3	0.19^{b}	99.23^{d}	113.97^{a}	40.28^{b}	16.63^{b}	25.02^{a}	9.83^{b}	30.05^{a}	56.41^{a}	33.14^{b}
$F_0$15	0.42^{a}	341.83^{a}	111.21^{a}	33.25^{c}	11.34^{c}	19.55^{c}	18.16^{a}	22.61^{b}	59.90^{b}	29.52^{c}
$F_0$50	0.29^{ab}	270.57^{b}	111.80^{a}	32.05^{c}	11.67^{c}	19.27^{c}	18.95^{a}	22.53^{b}	58.80^{ab}	28.42^{c}
MSD[r]	0.1579	48.405	2.8123	1.9176	1.8772	1.8559	2.1378	2.1252	3.2484	2.3634

Data shows average of all three replicates.
Note: Samples sharing the same superscripted letter were not significantly different ($p > 0.05$) from one another.
[r] Minimum significant difference.