Food Chemistry 141 (2013) 1740–1746

Contents lists available at SciVerse ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

# Carotenoid contents of extruded and non-extruded sweetpotato flours from Papua New Guinea and Australia ☆

Joel G. Waramboi [a], Michael J. Gidley [b], Peter A. Sopade [a,b,*]

[a] School of Agriculture and Food Sciences, University of Queensland, St. Lucia 4072, Australia
[b] Centre for Nutrition and Food Sciences, Queensland Alliance for Agriculture and Food Innovation, University of Queensland, St. Lucia 4072, Australia

ARTICLE INFO

*Article history:*
Received 2 November 2012
Received in revised form 6 March 2013
Accepted 22 April 2013
Available online 3 May 2013

*Keywords:*
Sweetpotato
Extrusion
Colour
Total carotenoids
β-Carotene
Carotenoid retention

ABSTRACT

Carotenoid contents of extruded and non-extruded flours of Papua New Guinean and Australian sweetpotato cultivars were studied, using spectrophotometry and high performance liquid chromatography (HPLC). The cultivars differed ($p < 0.05$) in their total carotenoid and β-carotene contents, and the Original Beauregard cultivar had the highest total carotenoid and β-carotene contents among the cultivars. The spectrophotometry (84–1720 μg/g solids) method generally over-estimated the total carotenoid content compared to the more specific HPLC (23–355 μg/g solids) method. Extrusion significantly ($p < 0.05$) decreased the $\Delta L^*$ Hunter colour values, while the $\Delta a^*$, $\Delta b^*$, total colour change ($\Delta E$), chroma (CR), and browning indices (BI) increased. With the extruder and screw configuration used, extrusion at 40% moisture and 300 rpm screw speed retained carotenoid maximally at more than 80%. This study reports, for the first time, carotenoids of flours from south Pacific sweetpotato cultivars, and carotenoid retention during extrusion.



## 1. Introduction

Interests in carotenoids are increasing as they contribute to combatting vitamin A deficiency (VAD). A serious global health problem, VAD leads to night blindness and immune deficiency (Ballart, Mugybuso, Ruhiye, Ndosi, & Basheke, 1998; WHO, 1994). Also, carotenoids, in their converted form (retinol), are effective against diseases such as diarrhoea, measles and anaemia (Sommer, Katz, & Tarwotjo, 1984). Sweetpotato, as a natural source of vitamin A, has been studied and consequently promoted to combat VAD (Kapinga, Byaruhanga, Zschocke, & Tumwegamire, 2009; Woolfe, 1992). Eating foods rich in carotenoids, such as coloured-flesh sweetpotato, can supply up to 3 mg/100 g of β-carotene, which is sufficient for the daily vitamin A requirements of children under 5 years of age (Jalal, Nesheim, Agus, Sanjur, & Habicht, 1998). The biological activity of carotenoids for vitamin A activity is measured as the retinol equivalent (RE) and retinol activity equivalent (RAE), where 1 RE is equivalent to 6 μg of all-*trans* β-carotene, and 1 RAE is equivalent to 12 μg of all-*trans* β-carotene or 24 μg of dietary α-carotene and β-cryptoxanthin (Breithaupt, Weller, Wolters, & Hahn, 2003; FAO/WHO, 1988; Higdon, 2003; Perera & Yen, 2007; US Institute of Medicine, 2001). There are more than 600 naturally occurring carotenoids, and up to 60 are in foods, with β-carotene, γ-carotene, lutein, violaxanthin, neoxanthin, zeaxanthin, and β-cryptoxanthin being the major ones (Perera & Yen, 2007; Rodriquez-Amaya & Kimura, 2004; van Hal, 2000).

Carotenoids in sweetpotato are related to its flesh colour, and the coloured-flesh cultivars are rich sources of carotenoids (Ameny & Wilson, 1997; Hagenimana, Carey, Gichuki, Oyunga, & Imungi, 1999; Takahata, Noda, & Nagata, 1993). Various studies have investigated carotenoids in sweetpotato, and their losses during food processing (Bechoff et al., 2010a; Bengtsson, Namutebi, Alminger, & Svanberg, 2008; Champagne et al., 2010; Duvivier, Hsieh, Lai, & Charles, 2010; Fonseca, Soares, Junior, Almeida, & Ascheri, 2008; Huang, Tanujaja, & Lum, 1999; Jung, Lee, Kozukue, Levin, & Friedman, 2011; Kidmose, Christensen, Agili, & Thilsted, 2007; Mosha, Pace, Adeyeye, Laswai, & Mtebe, 1997; van Jaarsveld, Marais, Harmse, Nestel, & Rodriquez-Amaya, 2006; van Ruremonde, 2010). Although some of these studies were conducted on sweetpotato cultivars from the south Pacific region, where Australia and Papua New Guinea are situated, most of the studies were based on conventional and household cooking techniques, with relatively little information on the effects of extrusion. Extrusion is a widely-used food processing technique, and sweetpotato, either alone or mixed with other materials (e.g. rice), has been extruded. In their studies on sweetpotato, with and without rice, Fonseca et al. (2008) found feed rate and screw speed to significantly reduce carotenoid retention in the extrudates. Possibly be-

☆ Presented in part at the Australian Food Science Summer School, Australian Institute of Food Science and Technology, University of Melbourne, Melbourne, VIC 3010, Australia. 1–3 February, 2012.

* Corresponding author at: School of Agriculture and Food Sciences, University of Queensland, St. Lucia 4072, Australia. Tel.: +61 7 334 67653; fax: +61 7 336 51177.
*E-mail address:* p.sopade@uq.edu.au (P.A. Sopade).

0308-8146/$ - see front matter Crown Copyright © 2013 Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.foodchem.2013.04.070

cause of the need for a stable extrusion system, these authors varied the extrusion conditions in a non-systematic manner, making it difficult to deduce the trends between carotenoid retention and extrusion conditions. A differently designed extrusion study with more processing details is, therefore, required to understand optimum extrusion conditions that maximise carotenoid retention in sweetpotato. Following on from our earlier studies on the physicochemical, functional and digestibility properties of sweetpotato cultivars from PNG and Australia (Waramboi, Dennien, Gidley, & Sopade, 2011; Waramboi, Gidley, & Sopade, 2012), the present study reports carotenoid contents of raw flours of coloured-flesh sweetpotato cultivars, and of extrudates from a notable cultivar with a view to understanding how extrusion affects carotenoid retention in sweetpotato.

## 2. Materials and methods

### 2.1. Sweetpotato cultivars and flour processing

Nine coloured-flesh sweetpotato cultivars (Beauregard, Beauregard II, Beerwah Gold, Beerwah Gold II, Honey Gold, Magenta Gold, Original Beauregard, L135, and Rocky Gold) were obtained from the Queensland Department of Agriculture, Fisheries and Forestry (DAFF), Gatton, QLD 4343, and the School of Agriculture and Food Sciences, University of Queensland, QLD 4072, Australia. The harvested roots were stored (8–10 °C) and processed within 48 h by washing, peeling, dicing, treating with 0.3% metabisulphite solution, drying (40 °C, 48 h, 50 m/min air velocity), and hammer-milling through a 1 mm retention sieve. The flours were stored at −18 °C as described previously (Waramboi et al., 2011), and were used for further studies.

### 2.2. Colour measurements

The $L^*$ $a^*$ $b^*$ Hunter colour parameters for the flours (Fig. 1) were measured using a Chromameter (Model CR-400, Konica Minolta Sensing Inc., Sakai-ku, Japan), and a standard white tile was used as the reference. Besides, total colour change ($\Delta E$), Chroma (CR), Hue angle (HA), and browning index (BI) were calculated according to Eqs. (1)–(5) (Bal, Kar, Satya, & Naik, 2011; Chen & Sopade, 2013; Demirhan & Ozbek, 2009), where; $\Delta L^* = L^*_{sample} - L^*_{tile}$; $\Delta a^* = a^*_{sample} - a^*_{tile}$; $\Delta b^* = b^*_{sample} - b^*_{tile}$ (Waramboi et al., 2011).

$$\Delta E \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

$$\text{Chroma} = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

$$\text{Hue angle} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (3)$$

$$\text{Browning index} = \frac{100(x - 0.31)}{0.17} \quad (4)$$

$$\text{where } x = \frac{a^* + 1.75L^*}{5.645L^* + a^* - 3.012b^*} \quad (5)$$

### 2.3. Extrusion processing

Extrusion processing was done, following published procedures and screw configuration (Yong, Chan, Garcia, & Sopade, 2011) at three moisture (30%, 35% and 40%) and screw speed (150, 220, 300 rpm) levels in the Prism Eurolab KX16 co-rotating twin-screw extruder (Thermo Prism, Emerald Way, ST15 0SR, UK). The Beerwah Gold II cultivar (Fig. 1) was extruded because of its visual colour intensity, and availability of raw material during the study period. The flour was fed (1.5 kg/h), using a single-screw volumetric powder feeder (Model KX16, Brabender Technologie KG, 47055 Duisburg, Germany), and water was supplied, using a peristaltic pump (Masterflex L/S 7523, Cole Parmer Instruments Company, Illinois, USA). The maximum barrel temperature (120 °C) was kept constant, and a slit die ($15 \times 2$ mm$^2$) was used. The flour feeder

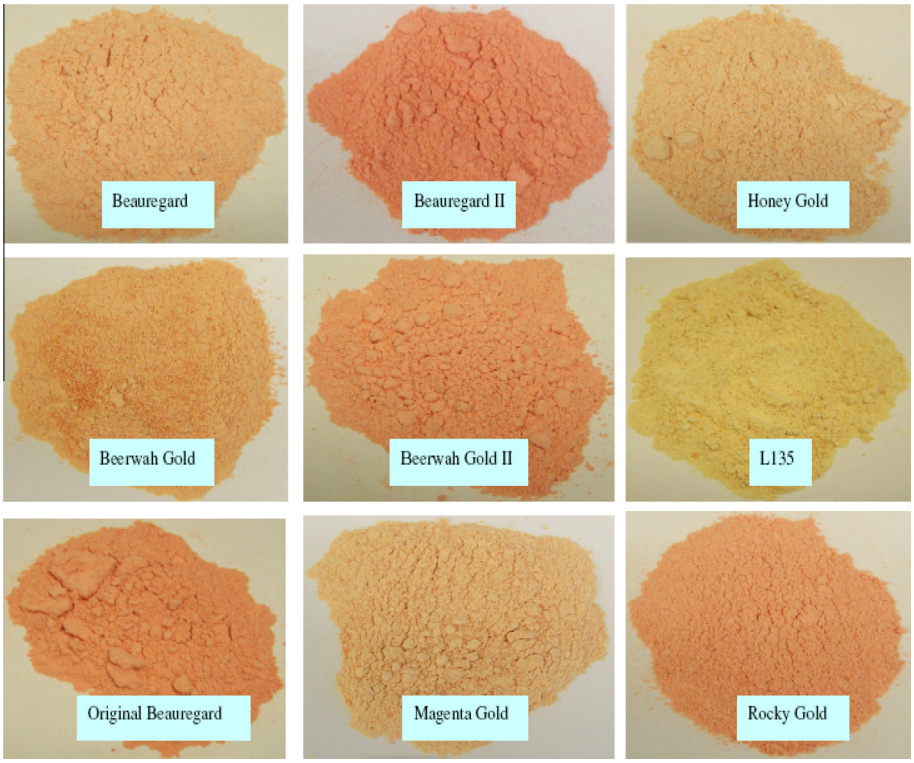


**Fig. 1.** Visual colour of raw non-extruded sweetpotato flours.