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# Relationship among the carotenoid content, dry matter content and sensory attributes of sweet potato

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ABSTRACT

The sensory characteristics of biofortified sweet potato in Africa were explored over a wide range of carotenoid (0.4–72.5 μg/g fresh weight) and dry matter contents (26.8–39.4%). The logarithm of the total carotenoid content was correlated with the dry matter content (declining by 1.2% with each doubling of the carotenoid content) and a wide range of sensory characteristics that involve visual, odour, taste and textural characteristics. Multiple linear regression models were developed. The logarithmic relationship of colour to the carotenoid concentration means that those varieties with a relatively low carotenoid content may appear to be of similar intensity to those with a much higher and hence nutritionally beneficial carotenoid content.



## 1. Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam) is among the most under-exploited of the developing world's major crops (Walker & Crissman, 1996). Traditionally, sweet potato varieties produced and sold in southern Africa have a pale-coloured flesh, but new biofortified orange flesh sweet potato varieties (OFSP) have been introduced that contain high concentrations of β-carotene (pro-vitamin A). Vitamin A deficiency is a leading cause of early childhood death and a major risk factor for pregnant and lactating women. It is estimated that, worldwide, tens of thousands of deaths occur annually among young children (McGuire, 1993). Impact assessment studies (Low, Walker, & Hijmans, 2001; Low et al., 2007) have indicated that OFSP can make a major contribution to alleviating vitamin A deficiency in sub-Saharan Africa and that the daily addition of orange-fleshed sweet potato to the diet could prevent vitamin A deficiencies in children, pregnant women and lactating mothers. An efficacy study (van Jaarsveld et al., 2005) in South Africa has demonstrated that consumption of 125 g OFSP improved the vitamin A status of children and can play a significant role in developing countries as a viable long-term food-based strategy for controlling vitamin A deficiency. A review of the importance of sweet potato, as an intervention food to prevent vitamin A deficiency, has recently been published by Burri (2011). Replacing the pale-fleshed varieties now grown by farmers, with new high β-carotene varieties, could benefit an estimated 50 million children under age 6 who are currently at risk. For example, the majority of children in Burundi, Rwanda and Uganda would benefit, as would about half of the children in Tanzania and to a lesser degree those in Ethiopia, Kenya and South Africa (Walker & Crissman, 1996).

Changes in appearance, taste and texture may be a barrier to consumer acceptance of fresh OFSP, particularly when it is a primary staple. Orange-fleshed sweet potato contains carotenoids (Bengtsson, Namutebi, Larsson Alminger, & Svanberg, 2008; Maoka, Akimoto, Ishiguro, Yoshinaga, & Yoshimoto, 2007; O'Connell, Ryan, & O'Brien, 2007). In Africa, consumers have been reported to prefer high dry matter varieties of sweet potato (Kapinga & Carey, 2003; Operia & Sun, 1988), and varieties of sweet potato with high carotenoid contents tend to have lower dry matter contents. The International Potato Center (CIP) has been breeding, specifically, for varieties of OFSP that are high in both carotenoid and dry matter contents.

The sensory characteristics of OFSP and non-orange varieties have been reported (Leighton, Schönfeldt, & Kruger, 2010; Ofori, Oduro, Ellis, & Dapaah, 2009; Tomlins et al., 2007). Orange-fleshed varieties are associated with sensory attributes, such as pumpkin flavour, watery texture and orange colour, while yellow and white varieties are associated with the descriptive terms, creamy colour, starchiness, hard texture, coarse texture, yellow colour, fibrous texture and sweet taste (Tomlins et al., 2007). Leighton, Schönfeldt,

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and Kruger (2010) reported that OFSP differed in colour, was sweeter and displayed flavour characteristics of yellow vegetables (such as butternut and pumpkin) when compared with white fleshed varieties. Ofori, Oduro, Ellis, and Dapaah (2009) relied on using acceptance criteria and did not use the sensory panel to describe the sensory attributes of OFSP or how it differed from white varieties. Little, however, appears to have been reported about the relationship between the sensory characteristics and the physical and chemical constituents, such as carotenoids or dry matter. For example, for consumers in Africa, it has been reported that they prefer high dry matter varieties of sweet potato (Kapinga & Carey, 2003; Operia & Sun, 1988). OFSP varieties of sweet potato, with high carotenoid contents, not only differ in colour but also tend to have lower dry matter contents.

Therefore, it would be of interest to explore how the sensory properties of sweet potato might vary with the carotenoid and dry matter contents.

In this study, the sensory characteristics of 11 sweet potato cultivars with varying carotenoid and dry matter contents in Uganda were compared.

## 2. Materials and methods

### 2.1. Sweet potato samples

Eleven sweet potato varieties were tested. These were orange-fleshed (Ejumula, Kakamega, SPK004/1, SPK004/6/6 and SPK004/1/1), yellow-fleshed (Tanzania and Naspot 1) and white-fleshed (Dimbuka, Nakakande, New Kawogo and Ndikirya N'omwami).

### 2.2. Cooking of sweet potato samples

Roots (fresh) were sorted to remove diseased and insect-damaged ones and boiled until the texture, assessed by a fork, was considered correct for eating. Preliminary trials indicated that this method was consistent and allowed for slight differences in cooking times with variety.

### 2.3. Ethical assessment and consent

This research has been assessed and approved by the University of Greenwich Research Ethics Committee. Written consent was sought from panellists participating in this study and they were informed that their participation was entirely voluntary and that they could withdraw from the panel at any time.

### 2.4. Sensory evaluation

Cooked sweet potato samples were scored by a semi-trained sensory panel, using a modified version of quantitative descriptive analysis (QDA) since standards were not provided (Meilgaard, Civile, & Carr, 2007). The sensory panel, which comprised 10 panellists, was conducted at the National Agricultural Research Laboratory, Uganda under ambient temperature and controlled lighting. The language used for the sensory testing was English. The panellists had been screened for familiarity with the product. Sensory attributes were generated during a preliminary focus group session guided by the panel leader. In total, 13 sensory attributes were developed for the cooked sweet potato, for which the group of panellists had a consensus. Sensory attributes generated were as follows:

- Sweet potato odour – odour characteristic of sweet potato
- Pumpkin odour - odour characteristic of pumpkins
- Smooth appearance – sweet potatoes that have an even surface
- Yellow colour – flesh that is yellow in colour
- Orange colour – flesh that is orange in colour
- White colour – flesh that is white in colour
- Uniform colour – sweet potato that is even in colour and with minimal variation
- Sweet taste – tastes like sugar
- Pumpkin taste – taste that is characteristic of pumpkin
- Crumbly texture (in the hand) – sweet potato is brittle and flaky when compressed by the fingers
- Soft texture – texture that is squashy and yielding
- Fibrous texture – the quality of being fibrous
- Watery texture – texture that is moist

After a period of training using these attributes, the 11 sweet potato samples were tested blind in duplicate by the panel and the order in which they were presented was random. At each session, four sweet potato samples (coded with 3-figure random numbers) were served on white paper plates, in random order, to each panellist. Cooked sweet potato samples (40 g) were tested by the panellists at ambient temperature (25–30 °C). Intensity for the sensory attributes was scored on a 100 mm unstructured scale, anchored with the terms 'not very' at the low end and 'very' at the high end.

### 2.5. Total carotenoid and dry matter content analysis of sweet potato

Total carotenoid content and dry matter were determined on the fresh roots. A total of five roots was randomly selected, for each variety, for analysis; these were quartered and pureed. Total carotenoid extraction (and analysis) was carried out in triplicate, following an existing method (Rodriguez Amaya and Kimura, 2004; Bechoff et al., 2010). 1–6 g of fresh tissue (the amount collected depended on an estimate of the level of total carotenoids in the sweet potato) was homogenised with 50 ml of methanol–tetrahydrofuran (THF) (1:1), using a Polytron PT1200E (Kinematica, Lucerne, Switzerland) homogeniser or an Ultra-turax (IKA Janke and Kunkel Labortechnik, Germany) macerator for 1 min. The carotenoid content was measured, using a UV–visible spectrophotometer (Genesys 10UV, VWR, UK), at a wavelength of 450 nm. Concentrations were determined by comparison with an external standard curve, using pure β-carotene (Sigma–Aldrich, Gillingham, UK) and an absorption coefficient of β-carotene in PE of 2592.14. Total carotenoid determination has been reported to be an acceptable technique to give a close estimate of trans-β-carotene content in OFSP, since 90% of the total carotenoid content of sweet potato is β-carotene (Bengtsson et al., 2008; Rodriguez Amaya & Kimura, 2004).

Dry matter determinations were assessed by drying triplicate 5 g samples (AOAC, 1984).

### 2.6. Statistical analysis

Analysis of variance, correlation analysis (Pearson), stepwise multiple linear regression and principal component analysis (correlation matrix) were carried out using SPSS (V 16.0) or XLSTAT (V 5.2, Addinsoft). A mixed effect model, for each of the sensory qualities, was used, with R (lme4 package). Multiple pairwise comparisons were undertaken, using the Tukey test with a confidence interval of 95%.

## 3. Results and discussion

### 3.1. Relationship between the sensory attributes and varieties of sweet potato with varying total carotenoid and dry matter contents

The sensory attributes of the 11 sweet potato cultivars tested were strongly significantly different with respect to variety (linear