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Original Article

Effects of various traditional processing methods on the all-*trans*-β-carotene content of orange-fleshed sweet potato

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Abstract

The effects of traditional preparation methods and drying procedures on the provitamin A carotenoid content of orange-fleshed sweet potato (OFSP) roots was determined by a high-performance liquid chromatography (HPLC) method. All-*trans*-β-carotene was the major provitamin A carotenoid and the mean content of seven improved OFSP cultivars ranged from 108 to 315 μg/g dry matter. The retention of all-*trans*-β-carotene was 78% when OFSP were boiled in water for 20 min. When OFSP were steamed for 30 min the retention was 77%, whereas deep-frying OFSP roots for 10 min resulted in retention levels of 78%. Drying slices of OFSP roots at 57 °C in a forced-air oven for 10 h reduced the all-*trans*-β-carotene content by 12%. Solar drying and open-air sun drying OFSP slices to a moisture content of $\leqslant$10% resulted in all-*trans*-β-carotene losses of 9% and 16%, respectively. The *cis*-isomer 13-*cis*-β-carotene was found in noticeable amounts in all processed samples, but not in any raw samples. The formation of 13-*cis*-β-carotene correlated with the original amount of all-*trans*-β-carotene found in the raw OFSP root. The high content of all-*trans*-β-carotene in the investigated improved OFSP varieties and the moderately low losses due to degradation and isomerization renders OFSP a suitable food source of provitamin A.

Keywords: Orange-fleshed sweet potato; *Ipomoea batatas*; β-Carotene; Food processing; Drying; Retention; Vitamin A deficiency (VAD); Bio-fortified staple foods

1. Introduction

The prevalence of vitamin A deficiency (VAD) is high in sub-Saharan Africa and particularly so in Uganda (Aguayo and Baker, 2005). In 2001, a Ugandan Demographic and Health Survey (UDHS, 2001) recorded the prevalence of VAD to 28% for 0–59-month-old children and to 52% for 15–50-year-old women. VAD is thus one of the major micronutrient deficiencies in the country. A number of different intervention strategies to address VAD are being promoted in developing countries. These include fortification (Dary and Mora, 2002), supplementation (Beaton et al., 1993), diet diversification (Gibson and Hotz, 2001) and use of bio-fortified staple foods (Welch, 2002). However, an inadequate health infrastructure and limited financial resources of many poor rural households calls for an alternative strategy to supplementation and fortification (Hagenimana and Low, 2000). The use of bio-fortified staple foods (i.e. varieties bred for increased mineral and vitamin content) has been justified as a sustainable food-based approach to reach a large section of the rural population who may not be reached by other intervention strategies (FAO/ILSI, 1997).

Orange-fleshed sweet potato (OFSP) is among the bio-fortified staples bred for high provitamin A carotenoid content (CIP, 2006). Sweet potato (*Ipomoea batatas*) is a major food crop in developing countries (Woolfe, 1992), and it is mainly consumed as boiled roots. Sweet potato is also commonly processed into dried slices and flour to preserve the roots for household use during off-season. OFSP may have the potential to prevent and combat VAD, as was indicated by a South African efficacy study of

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school-aged children that consumption of boiled and mashed OFSP improved their vitamin A status (van Jaarsveld et al., 2005). In order for communities to benefit from the high provitamin A carotenoid content of OFSP, preparation and processing methods should be optimized since these steps influence the retention levels of provitamin A carotenoids (Rodriguez-Amaya, 1997). Promotion of OFSP to farmers in Uganda has started and therefore knowledge about the retention levels of β-carotene in the processed sweet potato products is of great concern.

Provitamin A carotenoids are degraded by heat treatment and exposure to light during processing and during prolonged storage, but there is a lack of information regarding the retention of provitamin A carotenoids from traditional processing methods. Also, there is concern over conflicting values for carotenoid retention due to the intricate nature of the carotenoid analysis (Rodriguez-Amaya, 1997). The following study was undertaken to acquire knowledge about the retention of provitamin A carotenoids in boiled, steamed, deep-fried, and dried OFSP roots. In addition, the aim was to assess the natural variability of β-carotene content in improved OFSP cultivars and to measure the formation of *cis*-isomers during processing and drying. An additional objective was to evaluate color measurements of OFSP flour as a rapid screening method for the β-carotene content of fresh OFSP roots.

2. Materials and methods

2.1. Plant material

OFSP (*I. batatas*) root samples, which are improved sweet potato cultivars under field tests, were harvested 4.5 months after planting from Namulonge Agricultural and Animal Production Research Institute (NAARI), Uganda. The variety Ejumula was harvested 4 months after planting from a farmer site in the vicinity of NAARI. Table 1 shows the OFSP cultivars (one commercially released variety Ejumula and six field test varieties) used for the present study.

Table 1
Orange-fleshed sweet potato cultivars procured from Namulonge Agricultural and Animal Production Research Institute, Uganda

Sweet potato variety
Ejumula
SPK004
SPK004/6/6[a]
SPK004/6[a]
SPK004/1/1[a]
SPK004/1[a]
Sowola 6/94/9[b]

[a]Advanced yield trial.
[b]Intermediate yield trial.

2.2. Chemicals and standards

All chemicals were obtained from Sigma–Aldrich (Stockholm, Sweden) or Fischer Scientific GTF (Göteborg, Sweden). The water used for extraction and high-performance liquid chromatography (HPLC) analysis was generated by Millipore Milli-Q plus ultra-pure water system (Millipore, Solna, Sweden). All-*trans*-β-carotene standard (synthetic, crystalline, Type II, product C-4582) was purchased from Sigma–Aldrich (Stockholm, Sweden).

2.3. Preparation of samples

Four roots from each OFSP cultivar were randomly selected for each preparation method. Each root was washed, peeled and quartered longitudinally (from the stem end to the root end). Two opposite quarters were combined and kept frozen as a reference sample, while the remaining two quarters were prepared either by boiling, steaming or deep-frying. The weight was recorded before and after processing. Sweet potato samples were prepared as ready-to-eat products. Therefore, the processing times varied for the different methods. Sweet potatoes used for boiling were immersed in tap water contained in an open aluminum pot and boiled for 20 min. Sweet potatoes used for steaming were wrapped in banana leaves and placed on top of cut banana leaf stem ends to serve as a separator from the added tap water. The sweet potatoes were then steamed at 93 °C for 30 min in an aluminum pot with the lid on. Sweet potatoes used for deep-frying were immersed in locally produced sunflower oil with a temperature between 160 and 170 °C and deep-fried for 10 min.

2.3.1. Drying

Sweet potato roots (variety Ejumula) used for drying experiments were sliced to 1–2 mm thickness using a food processor (Braun Combi Max K600). A portion of approximately 50 g, taken as a reference sample, was placed in an amber polystyrene bottle, screw capped and stored in a freezer (–20 °C) prior to subsequent carotenoid analysis. The remaining slices (~450 g for each method) were used for drying. The procedure was repeated for four consecutive days. Sliced sweet potato for oven drying was spread out on aluminum foil lined trays, which were placed in an HT 4 forced-air cabinet oven dryer (Innotech, Altdorf, Germany) and dried at 57 °C for 10 h to a brittle texture. Sliced sweet potato for solar drying was spread out on 0.97 m × 0.77 m-sized plastic-meshed trays and placed in a tunnel solar dryer. The base of the solar dryer was lined with a black high-gauge polyethylene sheet. Drying temperatures varied between 45 and 63 °C in the solar dryer. Sliced sweet potato for open-air sun drying was spread out on a transparent low-gauge polyethylene sheet placed on a papyrus mat. Sliced sweet potato was dried under direct sunlight and occasionally turned to improve the drying process. Drying temperatures varied between 30 and 52 °C, measured directly above the sweet potato slices.