

Retention of β -carotene, vitamin C and sensory characteristics of orange fleshed sweet potato syrup during storage

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Abstract

Although orange-fleshed sweet potato (OFSP) is a rich source of β -carotene (pro-vitamin A), very few OFSP products have been developed. The objective of this study was to determine changes in sensory characteristics, β -carotene, and vitamin C contents of OFSP syrup during a storage period of 56 days at 4°C and 25°C. Unblended pulp syrup, unblended syrup, blended pulp syrup and blended syrup were developed. After 56 days of storage, β -carotene concentrations decreased from 2.25 mg/100 g to 0.70 and 0.51 mg/100 g in OFSP pulp syrups stored at 4 and 25°C respectively. While the β -carotene concentrations decreased from 2.20 mg/100 g to 0.47 and 0.34 mg/100 g for OFSP syrup stored at 4 and 25°C respectively. After 56 days of storage, vitamin C concentrations decreased from 9.6 to 1.8 mg/100 g in unblended OFSP syrups. Similarly in blended OFSP syrups vitamin C concentrations decreased from 9.7 to 1.4 mg/100 g after 56 days of storage. These results indicate that it is possible to develop OFSP syrups with an enhanced shelf-life but more effective strategies to prevent loss of β -carotene and vitamin C needs to be developed.

Keywords

Orange Fleshed sweet potato
 β -carotene
Vitamin C
Syrup
Sensory evaluation

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Introduction

Sweet potato (*Ipomea batatas* (L.) Lam) is an important food crop in the tropical regions of sub-Saharan Africa. It is grown in many tropical and subtropical regions and produces the highest amount of edible material per hectare per day (Horton and Fano, 1985). Sweet potato has a large potential to be used as a food security crop in developing countries with limited resources because of its short maturity time, ability to grow on under diverse climatic conditions, on less fertile soil and are relatively free from disease (Mayhew and Penny, 1988; Wireko-Manu, 2010). Moreover, sweet potato contains nutrients such as carbohydrates, β -carotene, vitamin B6, riboflavin, panthothenic acid, folic acid and minerals like calcium, copper, iron, manganese, and potassium which are important in human health and disease (Woolfe, 1992; Hou *et al.*, 2001). Sweet potatoes also contain other antioxidants such as anthocyanins, tocopherols and phenolic acids (Woolfe, 1992). 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 (Tomlins *et al.*, 2012). The β -carotene in OFSP is more biologically available than that from dark green

leafy vegetables and compares favorably with fresh carrots (Ukapbi and Ekeledo, 2009). Sweet potato is an excellent source of carotenoid because its major carotenoid is all trans- β -carotene, which exhibits highest provitamin A activity among the carotenoids (Bovell-Benjamin, 2007).

Vitamin A is an essential nutrient and its deficiency is a serious health issue for much of the developing world (Burri, 2011). Deficiency of vitamin A is a major cause of premature death in developing nations, particularly among children (Maiani *et al.*, 2009). Food fortification is an alternative method for ensuring adequate supply of vitamin A in the diet. However, food fortification can also be difficult to sustain, mostly because of the difficulties inherent in fortifying food (Burri, 2011). The food must be consumed by almost everyone, including the poorest individuals. It must be consumed with a narrow range of intakes: so that it prevents vitamin A deficiency in most people, but does not cause toxicity in people who can eat more than average amounts (Burri, 2011). Although, OFSP have the potential of solving vitamin A deficiency which is prevalent in many parts of sub-Saharan Africa, very few studies have been conducted to develop OFSP-based products that are appealing to consumers. Therefore, there is need to develop cheap, affordable, readily available, palatable and shelf-stable food products from sweet

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potatoes. Development of low and intermediate technologies that will process sweet potato into value added products at household level and village factory levels would promote its production and consumption and increase its economic value. For example, Sweet potato may be boiled, dried and milled into flour (Wireko-Manu and Oduro, 2010) baked, and sometimes the leaves are eaten. In some parts of East Africa sweet potatoes are sliced into strips, sun dried and later on soaked, boiled and consumed (Wireko-Manu and Oduro, 2010). A major constraint to increasing the use of sweet potato is that the diversity of processed products is relatively under-developed in Africa (Bruinsma, 1999). The industrial processing of sweet potatoes has not developed greatly in tropical Africa but they may be used as sweetening agents in canning, in sauces, and in the production of starch, ketchup, jam, wine, alcohol, noodles, desserts, candy, beverages, glucose syrup (Mayhew and Penny, 1988; Scott and Maldonado, 1998) and fruit juices. The similarity in fruits and sweet potato (more specifically OFSP) provides a basis for a hypothesis that sweet potato can be processed into products which are traditionally made from fruits such as jam, marmalade and drinks or beverages (Wireko-Manu and Oduro, 2010). Beverages are amongst the most widely accepted category of foods in many parts of the world. Development of bio-fortified OFSP beverages could lead to increased intake of β -carotene leading to prevention of vitamin A deficiency in the affected populations. It was reported that changes in appearance, taste and texture may be a barrier to consumer acceptance of fresh OFSP, particularly when it is a primary staple (Tomlins *et al.*, 2012). Processing operations such as blending and pasteurization may lead to deteriorative changes such as reduction of heat sensitive nutrients such as β -carotene, vitamin C and sensory attributes like colour, smell and taste. Therefore, the objective of this study was to determine the changes in sensory characteristics, β -carotene, and vitamin C contents of OFSP syrup during a storage period of 56 days at 4°C and 25°C.

Materials and Methods

Description of raw materials

The orange-fleshed sweet potatoes used in this study were obtained from Rwanda Agriculture Research Board (RAB) farm at Karama, Rwanda. Orange Fleshed Sweet Potatoes that were fresh, wholesome, plump without any wrinkles or soft spots or leaking were collected and handled carefully in order to avoid bruises and damages. The raw materials

Table 1. Composition of OFSP syrups

Component	Type of syrup			
	Unblended pulp syrup	Blended pulp syrup	Unblended syrup	Blended syrup
Juice (l)	0	0	1	1
pulp (l)	1	1	0	0
Orange juice (mL)	0	150	0	200
Sugar (g)	550	400	550	400
Sodium benzoate (g/l)	1.8	1.8	1.8	1.8
Citric acid (g/l)	10	10	10	10

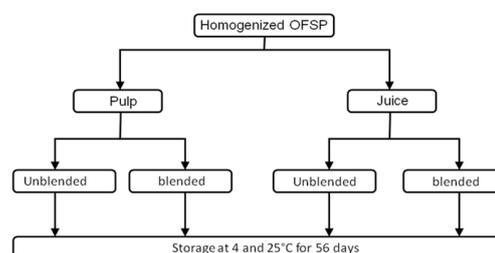


Figure 1. Experimental layout. Homogenized OFSP refers to sweet potatoes after peeling and crushing using a domestic kitchen blender.

were processed with 24 hours after harvesting.

Experimental design

A detailed description of the experimental design is shown in Figure 1. Each type of syrup produced was divided into two portions; one portion was unblended while the other portion was blended with orange syrup. The syrups produced were stored at 4°C and at 25°C for a period of 56 days. Analysis of β -carotene and vitamin C contents of the OFSP syrups was conducted immediately after processing and after 14, 28, 42, and 56 days of storage. While sensory evaluation was conducted after 1, 28 and 56 days of storage. All experiments were replicated at least two times and analyses were performed in duplicate.

Preparation of potato syrup

OFSP (6 kg) was washed, peeled, sliced into smaller pieces then soaked in a solution containing sodium metabisulphite (3 g/l) for 2 h to prevent enzymatic browning. The sliced OFSPs were crushed using a domestic kitchen blender to extract the juice. Water (1.2 liters) was added to the extracted juice and filtered. The extract obtained after filtration was referred to as OFSP juice while components that were retained in the filter were referred to as OFSP pulp. Both the OFSP juice and OFSP pulp obtained were used as raw materials for processing OFSP syrups. OFSP syrups produced were in unblended and blended forms namely; unblended pulp syrup, unblended syrup, blended pulp syrup, and blended syrup (Table 1). Two liters of juice and pulp were obtained. In case of OFSP pulp 1.8 liters of water was added. Blended OFSP pulp syrup was prepared by mixing 1 liter of pulp, 150 ml of orange juice and 400 g of sugar. While blended OFSP syrup was obtained by mixing 1 liter of OFSP juice with 200 ml of orange

juice and 550 g of sugar. Similar amounts of sugar were added to the unblended OFSP pulp syrup and OFSP syrup. The proportions of sugar and orange juice added to the respective OFSP syrups were determined after preliminary trials. Sodium benzoate and citric acid was added to all syrup products at a level of 1.8 g and 10 g/l respectively. The syrups were bottled pasteurized at 62°C for 30 min and stored as described above. After processing the syrups were stored in dark place to prevent photo degradation of β -carotene.

Determination of β -carotene

β -carotene content was determined using the method described by Wong (2005) with minor modifications. Two millimeters of OFSP was mixed with 10 ml of acetone (Park Scientific Limited, Northampton, UK) and transferred to 100 ml volumetric flask. The prepared mixture was filtered using a filter paper (whatman No. 1). The residue was again mixed with 10 ml of acetone and extracted as described above. The extract (25 ml) was evaporated to dryness on a rotary evaporator (Heidolph-Heizbad HB digit, Germany). Dried extract was dissolved in 1 ml of petroleum ether (Qualikems Fine Chemicals, New Delhi, India) and the solution purified using a chromatographic column (silica gel 60; length 10 cm; diameter 1 cm). The column was eluted with about 25 ml of petroleum ether and elute was collected in a flask. Two milliliters of elute was transferred into a cuvette and absorbance read using a spectrophotometer (M501 Single beam scanning UV/vis spectrophotometer: Camspec, Cambridge, UK) at 440 nm. Concentration of β -carotene was calculated using the standard curve data as follows;

mg of β -carotene per 100 g = μ g of β -carotene per 100 g as read from the

$$\frac{\text{Standard curve} \times \text{dilution factor} \times 100}{\text{Volume of sample (ml)} \times 100}$$

Determination of vitamin C

Vitamin C content was determined using the Indophenols method (AOAC, 2005) with minor modifications. Indophenol solution was prepared by dissolving 42 mg of sodium bicarbonate in 50 ml of distilled and deionized water (hereafter referred to as solution A). About 50 mg of sodium 2, 6 dichlorophenol indophenols (indophenols sodium) was dissolved in solution A. The mixture was transferred to a volumetric flask and water added to make a 200 ml solution. The prepared 2,

6 dichlorophenol indophenols solution was filtered through whatman filter (No.1).

Standardization of sodium 2,6 dichlorophenol indophenols solution

Two millimeter aliquot of the standard ascorbic acid solution was transferred to 50 ml Erlenmeyer flasks containing 5 ml of trichloroacetic acid (TCA: 10% v/v). Titration was performed rapidly with 2, 6 dichlorophenol indophenols from 25 ml burette until light but distinct rose-pink colour persisted for at least 5 seconds. Similarly, three blanks (composed of 5 ml of TCA and 2 ml of water) were prepared and titrated with 2, 6 dichlorophenol indophenols. After subtracting the average of blanks (approximately 0.1 ml) from standardization titrations the concentration of 2, 6 dichloroindophenol as mg of ascorbic acid was calculated and the value used for standardization.

Sample preparation

About 5 ml of OFSP syrup was measured and transferred to a 100 ml volumetric flask. The mixture was rigorously shaken and made up to 100 ml using TCA. The mixture was filtered immediately through a fluted filter paper.

Estimation of vitamin C

The filtrate (100 ml) was transferred to a conical flask. Titration was conducted rapidly with 2, 6 dichlorophenol indophenols solution until a light but distinct rose-pink colour persisted for at least 5 seconds. A blank determination was conducted using 11 ml of TCA reagent along with water sufficient to make the volume of the mixture equivalent to 15 ml plus the volume of the 2, 6 dichlorophenol indophenols solution determined in the standardization titration.

Calculation:

$$\text{Vitamin C content (mg/100 g)} = \frac{(A - B) \times C \times 1000}{W}$$

Where,

A = Volume in ml of the DCPIP used for sample titration.

B = Volume in ml of DCPIP solution used for sample blank titration.

C = Mass in mg of ascorbic acid equivalent to 1.0 ml of DCPIP standard.

W = Weight in g of sample.

Sensory evaluation

Sensory analysis was conducted using the five point hedonic scale where score of 5 points means like very much, a score of 4 points means like moderately,

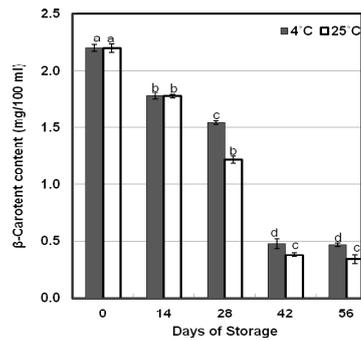


Figure 2a. Changes in β -carotene concentration of unblended OFSP pulp syrups. The concentration at 0 days of storage refers to β -carotene concentration immediately after processing of the OFSP syrup.

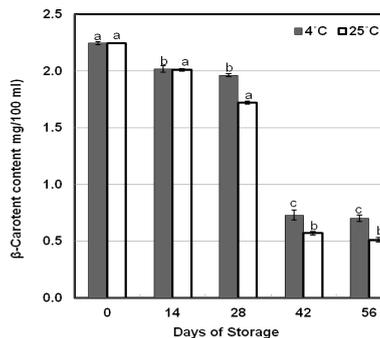


Figure 2b. Changes in β -carotene concentration of unblended OFSP syrups. The concentration at 0 days of storage refers to β -carotene concentration immediately after processing of the OFSP syrup.

a score of 3 points means neither like nor dislike, a score of 2 points means dislike moderately and a score of 1 point means dislike very much. Mean scores greater than 3 implies that the sensory attributes of the product evaluated were acceptable to the panelists. While mean scores below 3 points indicates that the sensory attributes of the products evaluated were unacceptable according to the panelist. A mean score of three means that the product was neither liked nor disliked by the panelist. Ten untrained panelists were used and were instructed to rinse their mouths before and after tasting the product. All syrup products were three digit coded to avoid bias results. The sensory parameters assessed were appearance, colour, odour, and taste.

Statistical analysis

All data were analyzed using one way analysis of variance (ANOVA) by means of statistical software (SPSS). Least significant difference (LSD) between means was determined at the level of $P \leq 0.05$.

Results

Changes in β -carotene concentration of OFSP syrup during storage

The β -carotene content of both unblended OFSP

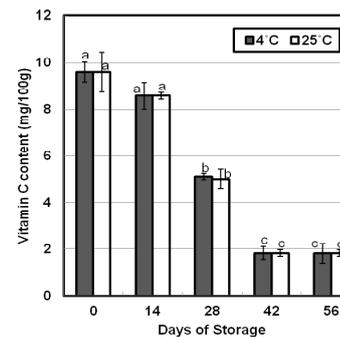


Figure 3a. Changes in vitamin C concentration of unblended OFSP pulp syrups. The concentration at 0 days of storage refers to β -carotene concentration immediately after processing of the OFSP syrup.

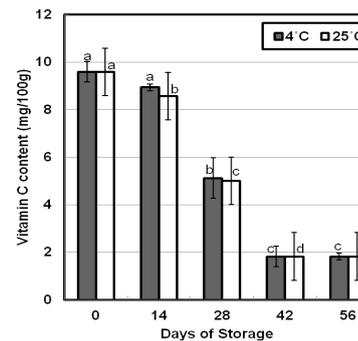


Figure 3b. Changes in vitamin C concentration of unblended OFSP syrups. The concentration at 0 days of storage refers to β -carotene concentration immediately after processing of the OFSP syrup.

pulp and unblended syrups decreased significantly ($P \leq 0.05$) during 56 days storage both at 4°C and 25°C (Figure 2a and 2b). Similar trends were observed in blended OFSP pulp syrup and OFSP syrup both at 4°C and 25°C (data not shown). β -carotene loss during 56 days of storage ranged from 68.9 to 84.5%. Within the first 14 days of storage, there was no significant ($P \geq 0.05$) difference in β -carotene content of unblended OFSP syrup and unblended OFSP pulp syrup stored at 4°C and 25°C but the β -carotene loss in unblended OFSP syrup was higher than in the OFSP pulp syrup. In between 28 and 42 days of storage there were significant decreases ($P \leq 0.05$) in β -carotene content of unblended OFSP syrup and unblended OFSP pulp syrup stored at 4°C and at 25°C. There were no significant ($P \geq 0.05$) changes in all OFSP syrup products between 42 and 56 days of storage. Generally, β -carotene losses were slightly higher in unblended syrup than unblended OFSP pulp syrup. At 28 days of storage at 4°C the β -carotene content in unblended OFSP syrup was 1.5 mg/100 ml while that of unblended OFSP pulp syrup was 2.0 mg/100 ml. The results of changes in β -carotene content of blended OFSP syrup and blended OFSP pulp syrup were very similar to that of unblended OFSP syrup and unblended OFSP pulp syrup respectively (data not shown). The study shows that the degree of

Table 2. Changes in sensory scores OFSP syrup during storage

Storage temperature	Days of storage	Sensory attribute*			
		Appearance	Colour	Odour	Taste
4°C	0	4.4 ^{ab} ± 0.7	4.5 ^a ± 0.7	2.9 ^a ± 0.9	2.0 ± 0.0
	28	4.3 ^a ± 0.5	4.4 ^a ± 0.5	2.7 ^a ± 0.5	2.0 ± 0.0
	56	2.6 ^b ± 0.5	2.9 ^b ± 1.0	2.8 ^a ± 0.7	1.0 ± 0.5
25°C	0	4.2 ^a ± 0.7	4.2 ^a ± 0.6	2.8 ^a ± 0.6	2.0 ± 0.0
	28	4.1 ^a ± 0.7	4.0 ^a ± 0.5	3.0 ^a ± 0.5	2.0 ± 0.0
	56	3.9 ^a ± 0.7	4.0 ^a ± 0.0	2.0 ^b ± 0.0	1.0 ± 0.0

*Values are mean sensory scores provided by 10 panelists. ^aMeans with the different lowercase letters were significantly different (P ≤ 0.05). Statistical comparison of means was made only on data within the same column.

Table 3. Changes in sensory attributes of OFSP pulp syrup during storage

Storage temperature	Days of storage	Sensory attribute*			
		Appearance	Colour	Odour	Taste
4°C	0	4.1 ^{abf} ± 0.6	4.3 ^{ab} ± 0.7	3.1 ^a ± 0.3	2.6 ^a ± 0.5
	28	4.7 ^a ± 0.5	4.6 ^a ± 0.5	3.2 ^a ± 0.4	2.5 ^a ± 0.5
	56	3.7 ^b ± 0.7	3.7 ^b ± 0.7	2.5 ^b ± 0.5	1.0 ^b ± 0.0
25°C	0	4.7 ^a ± 0.5	4.5 ^a ± 0.5	2.9 ^a ± 0.5	2.0 ± 0.0
	28	4.7 ^a ± 0.5	4.4 ^a ± 0.5	3.0 ^a ± 0.0	2.0 ± 0.0
	56	4.6 ^a ± 0.5	4.4 ^a ± 0.5	2.0 ^b ± 0.0	1.0 ± 0.0

*Values are mean sensory scores provided by 10 panelists. ^aMeans with the different lowercase letters were significantly different (P ≤ 0.05). Statistical comparison of means were made only on data within the same column.

loss of β-carotene content depends on the storage temperature, storage time and the type of syrup.

Changes in vitamin C concentration of OFSP syrup during storage

The vitamin C content of unblended OFSP syrup and unblended OFSP pulp syrup decreased during storage (Figure 3a and 3b). Similar trends were observed in blended OFSP pulp syrup and OFSP syrup both at 4°C and 25°C (data not shown). There were very little differences in between vitamin C content of OFSP syrup stored at 4°C and 25°C throughout the 56 days of storage. During the first 14 days of storage the loss of vitamin C was relatively lower compared to between 14 and 28 day of storage and between 28 and 42 days of storage. Changes in vitamin C content of blended OFSP syrups were very similar to that of unblended OFSP syrups (data not shown). These results indicated that temperature and the type of syrup were not the major factor influencing loss of vitamin C on OFSP juice. Generally, β-carotene and vitamin C concentration decreased slightly during the first 14 day of storage.

Changes in sensory scores of blended and unblended OFSP syrup during storage

The sensory scores of unblended and blended OFSP syrup during the 56 days of storage are shown in Table 2 and 3. There were no significant differences (P ≥ 0.05) in the sensory scores for appearance, colour and odour within the first 28 days of storage of both unblended and blended OFSP syrup. Although, there were significant decreases (P ≤ 0.05) in the sensory scores of appearance and colour of unblended OFSP syrup stored at 4°C between 28 and 56 days, no significant change (P ≤ 0.05) occurred in the appearance and colour of unblended OFSP

Table 4. changes in sensory attributes of blended OFSP syrup during storage

Storage temperature	Days of storage	Sensory attribute*			
		Appearance	Colour	Odour	Taste
4°C	0	4.4 ^{ab} ± 0.5	4.0 ^a ± 0.5	4.1 ^a ± 0.7	4.4 ^a ± 0.5
	28	4.0 ^a ± 0.5	4.3 ^a ± 0.5	3.8 ^a ± 0.6	4.2 ^a ± 0.4
	56	4.0 ^a ± 0.0	4.2 ^a ± 0.6	4.1 ^a ± 0.7	1.0 ^b ± 0.0
25°C	0	4.1 ^a ± 0.7	4.4 ^a ± 0.5	3.7 ^a ± 0.6	4.4 ^a ± 0.5
	28	4.3 ^a ± 0.8	4.1 ^a ± 0.9	3.7 ^a ± 0.8	4.5 ^a ± 0.5
	56	4.1 ^a ± 0.3	4.4 ^a ± 0.5	4.1 ^a ± 0.3	1.0 ^b ± 0.0

*Values are mean sensory scores provided by 10 panelists. ^aMeans with the different lowercase letters were significantly different (P ≤ 0.05). Statistical comparison of means were made only on data within the same column.

Table 5. Changes in sensory attributes of blended OFSP pulp syrup during storage

Storage temperature	Days of storage	Sensory attribute*			
		Appearance	Colour	Odour	Taste
4°C	0	4.4 ^{ab} ± 0.5	4.0 ^a ± 0.5	4.1 ^a ± 0.7	4.4 ^a ± 0.5
	28	4.4 ^a ± 0.5	4.0 ^a ± 0.5	4.1 ^a ± 0.3	4.2 ^a ± 0.3
	56	4.4 ^a ± 0.3	4.0 ^a ± 0.5	4.0 ^a ± 0.0	4.1 ^b ± 0.0
25°C	0	4.4 ^a ± 0.5	4.0 ^a ± 0.5	4.1 ^a ± 0.7	4.4 ^a ± 0.5
	28	4.4 ^a ± 0.5	4.1 ^a ± 0.3	4.2 ^a ± 0.4	4.5 ^a ± 0.7
	56	3.8 ^a ± 0.8	4.4 ^a ± 0.4	3.8 ^a ± 0.6	1.0 ^b ± 0.0

*Values are mean sensory scores provided by 10 panelists. ^aMeans with the different lowercase letters were significantly different (P ≤ 0.05). Statistical comparison of means were made only on data within the same column.

syrup stored at 25°C within this period. The sensory scores for odour and taste of unblended OFSP syrup were unacceptable to the panelists even immediately after processing. Blending improved the odour, and taste of OFSP syrup to a level that was acceptable to the panelists. Moreover, there was no significant decrease (P ≥ 0.05) in odour of blended OFSP potato syrup stored at 4°C and 25°C during 56 days of storage. These results show that odour and taste of OFSP syrup may not be appealing to consumers but blending with other fruit juices can greatly improve the taste and odour of OFSP syrup products.

Changes in sensory scores of blended and unblended OFSP pulp syrup during Storage

Generally, the changes in sensory scores for appearance and colour of both blended and unblended OFSP pulp syrup were similar to that of blended and unblended OFSP syrup (Table 4 and 5). However, the sensory scores for odour and taste of OFSP pulp syrup were higher than that of OFSP syrup and were acceptable to the panelists within the first 42 days of storage. In between 42 and 56 days of storage, sensory score for taste significantly decreased (P ≤ 0.05) to a level that was unacceptable the panelists. While the sensory scores for odour of unblended and blended OFSP syrup ranged between 2 and 3, that of blended and unblended OFSP pulp syrup ranged between 3.8 and 4.2 indicating using OFSP pulp in syrup processing results into products with a much more acceptable odour.

Discussion

Stability of β-carotene during storage is a major factor to be considered if OFSP consumption is to be applied in alleviating vitamin A deficiency. In this

study, the extent of β -carotene loss in the OFSP syrup products depended on storage temperature, storage time and type of syrup. On the basis of type of syrup, there were lesser losses in β -carotene content of OFSP pulp syrup than OFSP syrup indicating that OFSP pulp may contain compounds that retard β -carotene losses during storage which is advantageous. The decrease in β -carotene content of both OFSP syrup and OFSP pulp syrup were similar during the first 14 days of storage no matter the storage temperature indicating that there are other factors leading to loss of β -carotene. After 14 days of storage, loss of β -carotene in OFSP syrup stored at 25°C was higher than in those stored at 4°C. During the 56 days of storage losses in β -carotene content ranged from 68.9 and 84.5%. The exact components in OFSP pulp that aids in minimizing β -carotene losses was not elucidated in this study but it has been suggested that maltosyl α -cyclodextrin makes a complex with β -carotene and stabilizes it during storage of sweet potato juice (Tamaki *et al.*, 2007). This could be the main factor leading to lower β -carotene losses in OFSP pulp syrup since the pulp is likely to contain maltosyl α -cyclodextrin. Oxygen in the bottle head space could be a major factor attributing to loss of β -carotene during the first 14 days of storage. Over the range (0-21%) oxygen has a more marked effect on β -carotene than water activity (0.13 - 0.76) and temperature within the range of 10-40°C (Bechoff *et al.*, 2010). In the presence of air, the shelf life of perishable products is limited by two principal factors: (1) metabolic deterioration of the tissue and (2) growth of aerobic spoilage microorganisms (McConnell *et al.*, 2005). In a preliminary study we conducted no coliforms were detected in OFSP syrup but lactic acid bacteria (0 to 3.7 log CFU/ml), yeast (0 to 4.5 log CFU/ml) and total aerobic bacteria (0 to 4.7 log CFU/ml) were detected especially after 28 days of storage (data not shown). These findings indicate that microorganisms may play a role in spoilage of OFSP syrup particularly after 28 days of storage. However, studies also need to be conducted on the effect of removal of head space oxygen and replacing it with inert gases on β -carotene stability in OFSP syrup packed in bottles. Storage of OFSP syrups at 25°C was conducted to depict the actual handling conditions in sub-Saharan Africa where most low income communities do not own refrigerators and are most likely to suffer from vitamin A deficiency. If OFSP syrup is to be used in preventing vitamin A deficiency in poor communities, then measures need to be developed to prevent β -carotene losses during storage at room temperatures. The OFSP syrup processing technologies employed in this study needs

to be improved further to minimize loss of β -carotene during storage in order to ensure adequate and reliable β -carotene supply in the diet. Loss of β -carotene during storage is also used as a predictor of product shelf-life. The results obtained in this study indicate that it is possible to produce OFSP syrups that have a shelf-life of 28 days basing on the degree of β -carotene loss.

The trends in loss of vitamin C content in the OFSP syrups during 56 days of storage was similar that of β -carotene. Vitamin C is the most sensitive to destruction when the commodity is subjected to adverse handling and storage conditions (Lee and Kader, 2000). Losses are enhanced by extended storage, higher temperatures, presence of oxygen, alkaline pH and high temperature (Lee and Kader, 2000). It appears that pH is not major factor influencing the degradation of vitamin C because the pH of OFSP syrups was 3.6 and did not change significantly during storage (data not shown). Blanching and pasteurization prevent the action of ascorbic acid oxidase (Lee and Kader, 2000). Hence, pasteurization of the OFSP syrup at 62°C for 30 min may have prevented vitamin C losses during processing. About 81% of vitamin C was lost after storage for 56 days with the most significant losses occurring between 14 to 42 days of storage. Although, the factors causing the high vitamin C losses in OFSP is not yet been clearly studied, presence of oxygen in OFSP syrup could be a major factor. For instance, citrus juices in unopened bottles and cans contains higher ascorbic acid content and a low level of dehydroascorbic acid whereas those juices exposed to air and stored at warm temperatures contain more higher levels of dehydroascorbic acid and diketogulonic acid (Lee and Kader, 2000).

Sensory evaluation analysis results showed that appearance and colour of both blended and unblended OFSP syrups were acceptable to consumers. On the contrary, the odour and taste of OFSP syrups were unacceptable to consumers. Tamaki *et al.* (2007) reported that sweet potatoes exhibit a potential off-flavour in the boiling process. Pasteurization of OFSP syrup could have led to development of off-flavors. It was suggested that maltosyl α -cyclodextrin may serve as an effective deodorant against off-flavours of intermediate substances formed during the production of functional sweet potato juice (Tamaki *et al.*, 2007). Although, boiling of OFSP was reported to result in discolouration from orange to grayish brown leading low sensory scales (Ukpabi and Ekeledo, 2009), in this study no discolouration occurred during the pasteurization process. In this study, the main aim objective of blending was to enhance or mask off-flavours in OFSP syrup. Our

results showed that blending enhanced the taste and odour of both OFSP syrup and OFSP pulp syrup to a level acceptable to consumers, particularly within the first 28 days of storage. The decline in sensory scores to unacceptable levels between 28 and 56 days could be due to deteriorative reactions taking place in the OFSP syrup. The low sensory scores for odour and taste makes OFSP beverages less acceptable and competitive compared to fruit juices. However, OFSP syrup could be blended with other juice products to increase consumer acceptability and β -carotene content.

Conclusion

The results obtained in this study reveals that it is possible to develop β -carotene containing syrups from OFSP which could aid in preventing vitamin A deficiency in developing countries. The extent of β -carotene and vitamin C losses in the OFSP syrup products depended on storage temperature, storage time and type of syrup. On the basis of β -carotene and vitamin C stability the shelf life of OFSP syrup products developed in this study is 28 days though further confirmation is required using kinetic model experiments. Blending enhances the taste and odour of OFSP to levels that are acceptable to consumers. Further studies need to be conducted on means of improving β -carotene and vitamin C stability as well as enhancing the taste and odour of OFSP products. Development OFSP based syrup products could lead to increased consumption and utilization of OFSP. Increased consumption of OFSP could also decline in vitamin A deficiency and improved income.

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