

Nutritional Composition, B-carotene and Vitamin a Contribution of Orange-fleshed Sweet Potato (OFSP) Products From Selected South African Cultivars and Beauregard

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Abstract

Vitamin A deficiency (VAD) is widely recognised as a major public health problem in sub-Saharan Africa (SSA). Orange-fleshed sweet potato (OFSP), rich in β -carotene, offers a sustainable food-based intervention strategy to address VAD. However, the nutritional contribution of OFSP products depends on cultivar characteristics, formulation and processing methods, which influence proximate composition and carotenoid retention. This study evaluated the nutrient content of various OFSP-products developed from South African sweet potato (SP) cultivars (Khumo, Bophelo) and USA cultivar Beauregard. Four OFSP products, including flakes, instant porridge, crisps and pasta, were developed, and proximate composition, β -carotene content and retinol activity (RAE) were determined. The contribution of each product to the recommended dietary allowance (RDA) for vitamin A was calculated across different age groups. Statistically significant differences ($p < 0.001$) were observed among OFSP-products. Moisture content ranged from $5.15 \pm 0.03\%$ to $9.68 \pm 0.17\%$, protein from $2.18 \pm 0.01\%$ to 15.37% and fat from $0.74 \pm 0.12\%$ to $29.14 \pm 0.29\%$. Carbohydrate was the major macronutrient, with energy values between 1527 ± 2.0 and 2113.3 ± 0.57 kJ/100 g. Furthermore, β -carotene ranged from 7.52 ± 0.09 to 22.56 ± 0.65 mg/100 g, equivalent to RAE values of 626.94 ± 7.87 to 1880.0 ± 54.16 μ g/100 g. OFSP crisps retained the highest provitamin A, while instant porridge and pasta provided a balanced macronutrient profile due to composite formulation. This study demonstrated that 100 g of serving of OFSP flour or puree-based products could supply 100% of the vitamin A of RDA for children between 1–3, 4–8 and 9–13 years and pregnant women. These findings demonstrated that properly formulated OFSP products can serve as an effective, culturally adaptable vehicle for improving vitamin A intake and enhancing nutritional security.

1. Introduction

Vitamin A deficiency (VAD) is considered a major public health concern in sub-Saharan Africa (SSA), where dietary diversity is low and inadequate vitamin A intake contributes significantly to morbidity and mortality among vulnerable groups of the population, such as children, pregnant and lactating women [1, 2]. VAD leads to impaired immune function, increased risk of infection and preventable blindness [3]. Most recent systematic reviews suggest that in 2019, VAD affected about 334 million children (14.7% prevalence) in low and middle-income countries, with the highest rates in SSA and South Asia [1, 3]. VAD is the leading cause of preventable childhood blindness, accounting for 250 000–500 000 new cases of blindness annually [4]. Moreover, VAD increases the risk of mortality from infections such as measles and diarrhoea, contributing to 1–2 million preventable child deaths annually [4]. Despite supplementation campaigns in place, there are persistent gaps in reporting, emphasising the need for long-term viable dietary solutions [6].

Orange-fleshed sweet potato (OFSP), scientifically known as *Ipomoea batatas* L. (Lam), has emerged as a promising food-based strategy to address VAD due to its naturally high β -carotene content, which is converted to retinol in the body [7]. Beyond its provitamin A benefits, OFSP provides complex carbohydrates, dietary fibre and essential micronutrients, making it a nutritionally dense crop suitable for bio-fortification programs [8]. Its adaptability and productivity in African agro-ecologies further support its role in food security [9, 10]. However, fresh OFSP roots are highly perishable, limiting their year-round value. To overcome this, value-added products such as baked goods, snacks, convenience and fried food and beverages were developed [11]. These product forms help to extend shelf life and utilisation of sweet potato, but introduce processing challenges. Specifically, thermal and oxidation stress during drying, frying or extrusion can reduce β -carotene retention and change proximate composition [11]. Therefore, understanding how processing affects nutrient content and energy density is critical.

There is limited comparative data on the nutritional composition (moisture, protein, fat, fibre, carbohydrate and energy) and carotenoid retention (β -carotene, RAE) across various OFSP-derived products, particularly for common cultivars. Furthermore, few studies estimated the potential contribution of these products to dietary vitamin A requirements for

vulnerable population groups. Therefore, this study aims to (1) characterise the proximate composition of selected OFSP products (flakes, instant porridge, crisps and pasta), (2) quantify β -carotene and calculate the retinol activity equivalent (RAE), and (3) model the contribution of these products to the vitamin A requirements of different age groups. By identifying which product forms best retain provitamin A and provide meaningful dietary contribution, this study aims to provide evidence to better inform consumers on strategies to utilise OFSP as a food-based solution for VAD.

2. Materials and methods

2.1 Materials

The orange-fleshed sweet potato (OFSP) (*Ipomoea batata* L) cultivars (Fig. 1) used for this study were harvested from the Agricultural Research Council – Vegetables, Industrial and Medicinal Plants (ARC-VIMP) campus at Roodeplaat, Pretoria, South Africa. After harvest, healthy roots were selected. Other essential ingredients used were purchased from local retailer including Spar and Dis-Chem, South Africa.

Table 1
Characteristics
of sweet
potato
cultivars used

Origin	Khumo	Bophelo	Beauregard
	South Africa	South Africa	USA
Texture	Medium dry	Medium dry	Moist
Flesh colour	Orange	Orange	Orange
Skin colour	Light orange	Orange	Pink
Dry matter	23.2%	22.5%	18%

2.2 Methods

2.2.1 Preparation of OFSP flour and puree

Fresh roots of the selected OFSP cultivars (Fig. 1) were peeled using a hand peeler and washed with clean water. The washed OFSP roots were sliced using a vegetable cutter (Omni HLC-300 Electric) into 0.8 mm slices and dried using an AD100 Agri-Dryer (Serial DFACP18_038_ELEV| 220V) for 24h at 50°C. Following drying, the OFSP dried chips were crushed into flour with a Drotsky hammer mill, packed in a resealable aluminium foil bag, and stored in the dark at room temperature before analysis and use. For the production of puree, the clean OFSP roots were cut into cubes and then boiled for 30 minutes until soft. Following that, a food processor (Robot Coupe R652 7 L, France) was used for pureeing. The resultant puree was packaged in an aluminium foil zip-lock bag and stored at -20 °C until used.

2.2.2 Preparation of OFSP flakes

Flakes were formulated using OFSP flour prepared from two cultivars (Khumo and Bophelo). The formulation incorporated cereal grain flour, syrup, milk, water, baking powder and salt. The dry ingredients (OFSP flour, pearl millet flour, baking powder and salt) were first weighed and thoroughly mixed to ensure homogeneity. Wet ingredients (milk, syrup and water) were then gradually added while kneading until a uniform dough-like mixture was obtained. The

prepared mixture was spread evenly on a flat tray and dried in an oven at 70 °C overnight (Fig. 2). The dried flakes were allowed to cool at room temperature, packed in an airtight aluminium foil zip-lock bag and stored in a dark, cool environment prior to further nutritional analysis.

2.2.3 Preparation of OFSP instant porridge

Instant porridge was formulated using OFSP flour prepared from two cultivars, namely Khumo and Bophelo, as a major ingredient, constituting 40% of the total blend (Fig. 2). The OFSP flour was dry mixed with other ingredients, including defatted soy flour, pre-cooked maize flour, fine sugar, indigenous fruit powder, inulin, calcium phosphate (tribasic), salt, fat powder and vanilla flavouring.

2.2.4 Preparation of OFSP crisps

Fresh OFSP roots from Khumo and Bophelo cultivars were sorted to separate damaged roots, hand-peeled and washed under running water. The clean roots were then sliced into uniform 1 mm thick slices using a kitchen vegetable slicer. The slices were pre-dried with absorbent paper towels to remove surface moisture. Subsequently, the slices were deep-fried in canola oil at 195 ± 2 °C for 10 min using a Double electric 6 L fryer (Ashcom HEF-82A 6L Electric Deep Fryer). Immediately after deep-frying, slices were transferred to a Bennett Read air fryer (6 L Digital) at 100 ± 2 °C for 30 min to remove excess oil and improve crispness. The fried crisps were then cooled at room temperature and blotted with an absorbent paper towel to remove residual surface oil (Fig. 2). The final product was packaged in an aluminium foil zip-lock bag and stored in a cool and dark environment until analysis of proximate composition and β -carotene content.

2.2.5 Preparation of OFSP pasta

Pasta was formulated using OFSP puree prepared from two cultivars (Khumo and Beauregard) as main ingredients, constituting 40% of the total blend (Fig. 2). The OFSP puree was mixed with semolina flour at a ratio of 1:1 and kneaded thoroughly until a uniform dough was formed. The dough was rolled into a flat sheet and extruded into pasta using a kitchen pasta machine. The resultant was air-dried using an AD100 Agri-Dryer (Serial DFACP18_038_ELEV| 220V) at 70 °C for 3h. The final product was packaged in zip-lock aluminium foil and stored in a cool and dark environment until analysis of proximate composition and β -carotene content.

2.2.6 Method of analyses

Various laboratories were tasked to analyse the nutrients present in OFSP. Table 2 summarises the analytical methods applied for nutrient analysis and lists the different laboratories used.

Table 2

Summary of the method of analysis used to determine proximate analysis and β -carotene (β -carotene) content

Analysis	Method /techniques	Institution/laboratory
Proximate analysis		
Moisture	[12]	ARC-Irene Analytical Services, South African National Accreditation Services (SANAS), accredited laboratory
Dry matter	[12]	
Protein	[12]	
Fat	[12]	
Carbohydrates	[12]	
Crude fibre	[12]	
Ash	[12]	
Energy	[12]	
Fat-soluble vitamins		
β -Carotene	HPLC	ARC - Vegetable, Industrial and Medicinal Plants Analytical Bio testing Facility (VIMP – ABF)

2.2.7 Estimation of the contribution of OFSP-products to vitamin A requirements

Vitamin A values of OFSP-products were calculated as retinol activity equivalents (RAE) using an RAE conversion factor of 12 μg β -carotene to 1 μg retinol [13]. The contribution of each OFSP product to the vitamin A requirements for different groups of people was determined. The groups were children (1–3 years), children (4–8), adolescents (9–13 years), adults (above 14), pregnant women and lactating mothers.

2.2.8 Statistical analyses

One-way analysis of variance (ANOVA) was used to test for differences among OFSP products on the dependent variables. SPSS (IBM Corporation, Armonk, New York, USA) and Statistix 10.0 (Antietam Trl, Tallahassee) were used for data and correlation analysis. Significant differences between means were determined using Tukey's Honestly Significant Difference (HSD) at 5% probability level ($p < 0.05$).

3. Results and discussion

3.1 Proximate composition

As shown in Table 3, moisture content (MC) differed significantly among OFSP products evaluated ($p < 0.001$). MC values ranged from $5.15 \pm 0.03\%$ to $9.68 \pm 0.17\%$ across all products. OFSP flakes exhibited the lowest MC (5.15 ± 0.03 to $5.79 \pm 0.07\%$), followed by instant porridge (6.87 ± 0.14 to $6.99 \pm 0.31\%$). In contrast, slightly higher MC was observed in crisps (8.43 ± 0.33 to $9.68 \pm 0.17\%$) and pasta products (8.76 ± 0.05 to $9.67 \pm 0.02\%$). These differences reflect the distinct processing methods applied to each product. Drying during flakes and instant porridge preparation reduced moisture substantially, whereas frying of crisps and pasta formulation generally retained higher MC due to

short drying time and lower thermal dehydration. Moreover, OFSP flakes and instant porridge were formulated using flour, whereas crisps and pasta were prepared from fresh roots and puree, respectively. These differences in raw material forms contributed to the variation observed in moisture retention. The findings of the present study align with previous studies indicating that MC in sweet potato-based products varies widely depending on processing methods, product composition and drying conditions [14, 15]. Studies on dehydrated sweet potato flours have shown MC below 10%, consistent with the values observed in OFSP flakes and instant porridge products, which supports their suitability for extended shelf life and reduced microbial susceptibility [15–17]. Similarly, slightly higher MC in snack products such as crisps and in pasta formulation have been reported, as these products often retain higher residual moisture content after processing due to oil absorption and partial dehydration rather than complete drying [15, 18].

Protein content differed significantly among OFSP products ($p < 0.001$), ranging from $2.18 \pm 0.01\%$ in crisps to $15.37 \pm 1.05\%$ in instant porridge (Table 3). Instant porridge recorded the highest protein content from 14.96 ± 0.26 to $15.37 \pm 1.05\%$, followed by pasta from 9.83 ± 0.028 to $10.97 \pm 0.00\%$. The comparatively high protein content observed in instant porridge and pasta products might be attributable to formulation rather than OFSP cultivar properties. In this study, instant porridge was formulated with protein-rich ingredients such as soy flour, which enhanced the amino-acid profile of the final product [19, 20]. Similar effects have been reported for pasta formulation, whereby the incorporation of soy flour significantly enhanced protein content. For instance, [21] reported that enriching pasta with 50% soy increased its protein by 54%. The protein content of these OFSP products in the current study is within the range of staple crops such as maize (9.4%), rice (7.1%), wheat (12.6%) and sorghum (11.6%). In particular, the protein content of instant porridge exceeded that of staple crops, indicating its potential value for improving dietary protein intake in populations vulnerable to protein malnutrition. OFSP crisps showed lower protein content (2.18 ± 0.01 to $3.42 \pm 3.03\%$) compared to other products. Studies show that raw OFSP roots contain only about 0.859–12% protein, depending on cultivar [22, 23]. The crisps in this study are prepared from slices of fresh roots; their protein content reflects the naturally low protein composition of the cultivar. In addition, deep-frying drives off moisture and replaces it with oil. As a result, increase the fat fraction of the product, which reduces the relative percentage of protein in the product's proximate composition [24].

Fat content of OFSP products ranged from $1.26 \pm 0.07\%$ to $29.14 \pm 0.29\%$, with flakes, instant porridge and pasta recording the lowest, while crisps had the highest. The low-fat content in instant porridge and pasta is beneficial because of the risk of hydrolytic and oxidative rancidity, improving storage stability [25]. In contrast, crisps showed significantly higher fat content (24.32 ± 0.38 to $29.14 \pm 0.29\%$), confirming extensive oil absorption during frying. This aligns with previous findings showing that frying can increase the lipid content of starchy products from less than 2% to over 20% [26–28]. Oil absorption depends on temperature, time, cellular disruption or pore formation during moisture loss. Lower frying temperatures tend to increase absorption due to prolonged contact with oil [29]. According to [24], the absorbed oil accumulates on the surface of the fried food during frying and then migrates to the inner side of the food during cooling, leading to high fat content. The fat content observed in this study for OFSP crisps is comparable to commercial fried snacks such as potato chips (18–45%) [30].

Carbohydrate content also varied significantly ($p < 0.001$), ranging from $56.39 \pm 0.58\%$ to $80.35 \pm 1.62\%$ (Table 3), with most OFSP products containing 72–80%. This agrees with the reported range between 50.7–83% reported for OFSP products [13]. The instant porridge results are consistent with [31], who found carbohydrate content ranged between 66.94–76.11% in instant porridge, while pasta carbohydrate content values agree with [32], who found 74.61–77.47% in Bambara-OFSP pasta. The higher carbohydrate content in dried products (flakes and instant porridge) in this study reflect concentrate effects resulting from water removal during dehydration [33]. Similarly, [34] reported 77.8% carbohydrate in a composite flour containing 80% OFSP. The strong negative correlation ($r = -0.93$, $p < 0.0001$) between carbohydrate and fat content confirms the displacement effect, where absorbed oil reduces the relative carbohydrate

proportion in OFSP crisps (Table 4). This relationship is well documented in fried products [27, 35]. Additionally, reduced carbohydrate content in crisps may result from leaching of water-soluble sugars before frying or partial degradation via the Maillard and caramelisation reactions [36, 37].

Crude fibre content differed significantly among OFSP products ($p < 0.001$), ranging from $2.10 \pm 0.49\%$ with the crisps recording the highest and flakes the lowest (Table 3). The fibre content recorded in the current study exceeded values reported by [13], who found fibre content from 1.0 ± 0.1 to $2.8 \pm 0.8\%$ for a variety of OFSP products. The high fibre content in crisps aligns with the varietal difference reported by [22] and supports the influence of genotype on fibre content [38]. The flake products also showed increased fibre due to water loss during drying, which concentrated solids [39]. A similar effect occurs when OFSP flour was incorporated into the formulation of instant porridge, enhancing total fibre content. Ash content also differed significantly ($p < 0.001$), ranging from $0.64 \pm 0.05\%$ to $4.48 \pm 0.01\%$ across all products. OFSP flake products showed the highest ash values, while pasta had the lowest. These results fall within the 0.7–8% range reported for a variety of OFSP products [25, 40]. Instant porridge contained $3.14 \pm 0.12\%$ to $3.48 \pm 0.18\%$, consistent with findings by [41]. Variation may be attributed to cultivar and formulation differences [22, 42]. High ash content in OFSP flakes and instant porridge indicates a substantial mineral contribution, suggesting their potential in addressing micronutrient deficiencies [13].

Energy content also varied significantly ($p < 0.001$) across OFSP products, ranging from 1527 ± 0.0 to 2113.3 ± 0.57 kJ/100 g. The flakes showed energy content from 1573.7 ± 31.08 to 1591.3 ± 22.47 kJ/100 g, similar to results reported by [13] and [43], but lower than the 1716.7 kJ/100 g observed by [44]. Instant porridge products recorded energy range from 1547 ± 7.00 to 1559 ± 6.55 kJ/100 g, comparable to 1552.98 to 1676.62 kJ/100 g reported for maize-OFSP composite porridge, but lower than formulation enriched with soybeans, amaranth grains, pumpkin seeds and OFSP flour [45]. Pasta products contained 1527 ± 2.00 to 1559.3 ± 8.96 kJ/100 g, higher than reported for Gnocchi pasta and noodles products [46, 47]. Among all products, crisp products recorded the highest energy content values of 1997.3 ± 6.35 to 2113.3 ± 0.57 kJ/100 g, reflecting their high fat content and oil absorption during frying.

Table 3
Proximate composition and nutritional properties of different OFSP-based products

Products	Moisture (% DW)	Dry matter (% DW)	Protein (% DW)	Fat (% DW)	Carbohydrates (% DW)	Crude Fibre (% DW)	Ash (% DW)	Energy (kJ/100 g DW)
K-Flakes	5.15 ± 0.03 ^e	94.84 ± 0.03 ^a	8.13 ± 0.15 ^{bc}	1.87 ± 1.54 ^{cd}	80.35 ± 1.62 ^a	2.10 ± 0.49 ^b	4.48 ± 0.01 ^a	1573.7 ± 31.08 ^{cd}
B- Flakes	5.79 ± 0.07 ^d	94.2 ± 0.07 ^b	7.36 ± 0.26 ^c	2.97 ± 0.92 ^c	79.75 ± 0.93 ^a	2.98 ± 0.77 ^b	4.1 ± 0.27 ^a	1591.3 ± 22.47 ^c
K- Instant Porridge	6.99 ± 0.31 ^c	93.01 ± 0.31 ^c	15.37 ± 1.05 ^a	1.26 ± 0.07 ^{cd}	72.89 ± 1.60 ^b	2.98 ± 1.64 ^b	3.48 ± 0.18 ^b	1547 ± 7.00 ^{de}
B-Instant Porridge	6.87 ± 0.14 ^c	93.13 ± 0.14 ^c	14.96 ± 0.26 ^a	1.46 ± 0.20 ^{cd}	73.55 ± 0.14 ^b	2.71 ± 0.32 ^b	3.14 ± 0.12 ^{bc}	1559 ± 6.55 ^{cde}
K-Crisps	8.43 ± 0.33 ^b	91.57 ± 0.33 ^d	2.18 ± 0.01 ^d	29.14 ± 0.29 ^a	56.39 ± 0.58 ^c	9.70 ± 4.72 ^a	2.79 ± 0.03 ^c	2113.3 ± 0.57 ^a
B-Crisps	9.68 ± 0.17 ^a	90.31 ± 0.17 ^e	3.42 ± 3.03 ^d	24.32 ± 0.38 ^a	59.45 ± 3.33 ^c	4.23 ± 1.38 ^b	2.32 ± 0.10 ^d	1997.3 ± 6.35 ^b
K-Pasta	9.67 ± 0.02 ^a	90.33 ± 0.02 ^e	9.83 ± 0.28 ^{bc}	0.74 ± 0.12 ^d	78.36 ± 0.16 ^a	2.63 ± 1.04 ^b	1.38 ± 0.02 ^e	1527 ± 2.00 ^e
BG-Pasta	8.76 ± 0.05 ^b	91.23 ± 0.05 ^d	10.97 ± 0.00 ^b	0.96 ± 0.43 ^d	78.65 ± 0.41 ^a	2.44 ± 0.48 ^b	0.64 ± 0.05 ^f	1559.3 ± 8.96 ^{cde}

Values are mentioned as Mean ± SD (n = 3)

Different subscripts in the same column indicate that means were significantly different ($p < 0.05$)

Mean values are given on a dry weight basis (DW)

OFSP: Orange-fleshed sweet potato; K= Khumo; B = Bophelo; BG = Beaugard

Table 4
Relationship between the nutritional properties, β -carotene and retinol activity equivalent

Moisture	Moisture	Dry	Carbohydrate	Protein	Crude fibre	Ash	Fat	Energy	β	RAE
	1									
Dry	1	1								
Carbohydrate	-0,482	0,482	1							
Protein	-0,267	0,267	0,557	1						
Crude fibre	0,206	-0,206	-0,682	-0,518	1					
Ash	-0,851	0,851	0,094	0,002	-0,027	1				
Fat	0,431	-0,431	-0,943	-0,798	0,711	-0,060	1			
Energy	0,408	-0,408	-0,936	-0,802	0,724	-0,052	0,998	1		
β	0,327	-0,327	-0,874	-0,345	0,746	-0,092	0,780	0,787	1	
RAE	0,327	-0,327	-0,874	-0,345	0,746	-0,092	0,780	0,787	1	1
ND: Bold values are significant										

3.2. Beta (β)-carotene and Retinol Activity Equivalent (RAE)

Table 5 presents the β -carotene and retinol activity equivalent (RAE) content of OFSP products with their estimated contribution to the daily vitamin A requirement for different population age groups. The β -carotene of OFSP products differed significantly ($p < 0.001$), ranging from 7.52 ± 0.09 mg/100 g to 26.56 ± 0.65 mg/100 g. Among the products, OFSP crisps showed the highest β -carotene, followed by instant porridge, pasta and flakes. The vibrant orange colour of the products shown in Fig. 2, particularly the crisps, visually correlates with these high levels of β -carotene detected via HPLC. The higher β -carotene content observed in crisp products can be attributed to the high initial β -carotene concentration of raw OFSP varieties, concurrently with the concentration effect resulting from moisture loss during deep-frying. In this study, crisp products recorded β -carotene values (14.13 to 22.56 mg/100 g), reflecting both the concentration effect of dehydration and partial oxidation losses associated with deep-frying. While the β -carotene content was higher in crisps (up to 22.56 mg/100 g) due to moisture loss (dropping to 8–9%), the high frying temperature of $195 \pm 2^\circ\text{C}$ likely caused significant oxidative degradation compared to the raw root baseline. Consistent with previous reports, the β -carotene concentration of raw OFSP roots is the primary determinant of β -carotene content in the final product, even after processing. Several studies have demonstrated that β -carotene content varies widely among OFSP varieties, even grown under similar growing conditions [22, 42, 48]. The variation observed among the OFSP products in this study may be linked to cultivar-specific differences in carotenoid accumulation as well as processing-related factors such as drying temperature, formulation and matrix interaction that affect carotenoid stability [22]. In contrast, flake and pasta products showed comparatively lower β -carotene content (7.52 to 10.43 mg/100 g), probably due to increased carotenoid degradation during processing involving higher temperatures and exposure to oxygen. Previous studies have reported that β -carotene degradation in extruded or drum-dried products can exceed 50%, depending on drying conditions [49, 50].

The RAE values were calculated on a dry weight basis ($\mu\text{g}/100$ g), ranging from 626.94 ± 7.87 $\mu\text{g}/100$ g to 1880.0 ± 54.16 $\mu\text{g}/100$ g (Table 5). As expected, RAE values corresponded closely with β -carotene content, given that 1 μg RAE equals 12 μg dietary β -carotene content [13]. The high RAE in OFSP products reflect their potential as sources of

provitamin A carotenoids. Notably, the mean RAE values recorded in the current study were higher than those previously reported for comparable OFSP-based products [13]. The estimated contribution of a 100 g serving of OFSP products to the recommended dietary vitamin A allowance varied according to product form and age group (Table 5). In this study, flake, instant porridge and pasta formulation contained 40% of OFSP flour and puree. Based on their RDA of retinol, results showed that these products meet 100% of the daily requirement among children from the ages of 1–3, 4–8 and 9–13 years. Among adults, a 100 g serving of OFSP flakes and pasta could provide between 69.66 ± 0.87 to $70.09 \pm 2.73\%$ and 76.14 ± 0.82 to $96.60 \pm 9.65\%$ of the RDA of retinol. The OFSP crisps, when consumed as a snack, could provide 100% of the RDA of retinol for adult, pregnant women and lactating mothers. Similarly, a 100 g serving of OFSP flakes could provide about 82% of the daily requirement for pregnant women, while a lactating mother may still require 50% additional retinol to fulfil both their needs and those of their children. OFSP instant porridge could supply lactating mothers with 88.47 ± 1.38 to $100.02 \pm 1.56\%$ of the RDA retinol, while the pasta could provide between 57.10 ± 0.62 to $98.14 \pm 0.74\%$. In the current study, crisp products retain more provitamin A than flakes or pasta, suggesting their suitability as a vehicle for improving vitamin A intake in vulnerable populations. The findings suggest that consumption of as little as 40 g of OFSP-based flour or puree products per day could meet 100% of the vitamin A requirement for preschool children and pregnant women. These results are consistent with intervention studies demonstrating that incorporation of OFSP into diets increases plasma retinol and β -carotene content [51].

Table 5
 β -carotene (mg/100 g DW) and RAE (μg /100g DW), and contribution of OFSP products (100 g) to vitamin A requirement in different age groups

Product	β -carotene (mg/100 g DW)	RAE (μg /100 g DW)	1–3 years (%) (RDA = 300 ^a)	4–8 years (%) (RDA = 400 ^a)	9–13 years (%) (RDA = 600 ^a)	Above 14 years (RDA = 900 ^a)	Pregnant women (%) (RDA = 770 ^a)	Lactating mothers (%) (RDA = 1200 ^a)
K-Flakes	7.57 ± 0.29^e	630.28 ± 24.53^e	210.28 ± 2.48^e	157.71 ± 6.13^e	105.14 ± 4.08^e	70.09 ± 2.73^e	81.93 ± 3.18^e	52.57 ± 2.04^e
B- Flakes	7.52 ± 0.09^e	626.94 ± 7.87^e	208.98 ± 2.62^e	156.74 ± 1.96^e	104.49 ± 1.31^e	69.66 ± 0.87^e	81.42 ± 1.02^e	52.24 ± 0.65^e
K-Instant porridge	12.74 ± 0.19^c	1061.7 ± 16.64^c	353.89 ± 5.54^{cd}	265.42 ± 4.16^c	176.95 ± 2.77^c	117.97 ± 1.84^c	137.88 ± 2.16^c	88.47 ± 1.38^c
B- Instant porridge	14.4 ± 0.22^b	1200.3 ± 19.04^b	400.09 ± 6.34^b	300.07 ± 4.76^b	200.05 ± 3.17^b	133.36 ± 2.11^b	155.88 ± 2.47^b	100.02 ± 1.56^b
K-Crisps	22.56 ± 0.65^a	1880.0 ± 54.16^a	626.67 ± 18.05^a	470.00 ± 13.53^a	313.33 ± 9.02^a	208.89 ± 6.02^a	244.15 ± 7.03^a	156.67 ± 4.53^a
B- Crisps	14.13 ± 0.10^b	1177.8 ± 8.90^b	392.59 ± 2.96^b	294.45 ± 2.22^b	196.29 ± 1.48^b	130.86 ± 0.99^b	152.96 ± 1.15^b	98.14 ± 0.74^b
K-Pasta	8.22 ± 0.29^e	685.28 ± 7.46^e	228.28 ± 8.18^e	$171.321.86^e$	114.21 ± 1.24^e	76.14 ± 0.82^e	88.99 ± 0.96^e	57.10 ± 0.62^e
BG-Pasta	10.43 ± 1.04^d	869.44 ± 86.84^d	289.81 ± 28.94^d	217.36 ± 21.71^d	144.91 ± 14.47^d	96.60 ± 9.65^d	112.91 ± 11.27^d	72.45 ± 7.23^d

Values are mentioned as Mean \pm SD (n = 3)

Different subscripts in the same column indicate that means were significantly different ($p < 0.05$)

Mean values are given on a dry weight basis (DW)

The retinol activity equivalency (RAE) factor of 1 μg (vitamin A activity) = 12 μg all-trans- β -carotene was used [13]

OFSP: Orange-fleshed sweet potato; K= Khumo; B = Bophelo; BG = Beauregard

RDA: recommended dietary allowance

^a RDA adopted from [13]

4 Conclusion

This study demonstrated that OFSP products differed significantly in proximate composition, β -carotene retention and vitamin A contribution depending on product type, formulation and processing method. Carbohydrates were the predominant macronutrient across all products, while protein content was enhanced in instant porridge and pasta due to composite formulation, and fat and energy content were highest in OFSP crisps as a result of deep-frying. The β -carotene and RAE values varied significantly, with the crisps showing the highest provitamin A content compared with other products. Dietary calculation indicated that consumption of about 40 g of OFSP-based products could provide 100% of the recommended dietary allowance for vitamin A among children aged 1–3, 4–13 years, and pregnant women. These findings confirm the potential of properly processed OFSP products as effective food-based strategies for improving vitamin A intake.

Declarations

Author contributions

KS, FMM, and PM conducted all experimental, analytical work, statistical analysis and manuscript writing collaboratively. ND, MB, EC and SML provided essential guidance during methodology development, providing critical reviews and feedback to ensure the academic rigour and clarity of the manuscript.

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Data availability:

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

The cultivated orange-fleshed sweet potato roots collection was carried out strictly in accordance with all applicable local and national guidelines, rules, and regulations.

Plant material collection and guidelines

Sweet potato (*Ipomoea batata* L) plant material were collected in compliance with local and national regulations governing research on cultivated plants. No endangered or protected species were involved. The authors confirm that

the necessary permission to collect the sample have been obtained.

Consent to participate

Not applicable.

Clinical trial number

Not applicable

Consent for publication

Not applicable

Competing interest declaration

The authors declare no competing interests

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Figures



Figure 1

Pictures of OFSP cultivars used: Khumo, Bophelo and Beauregard

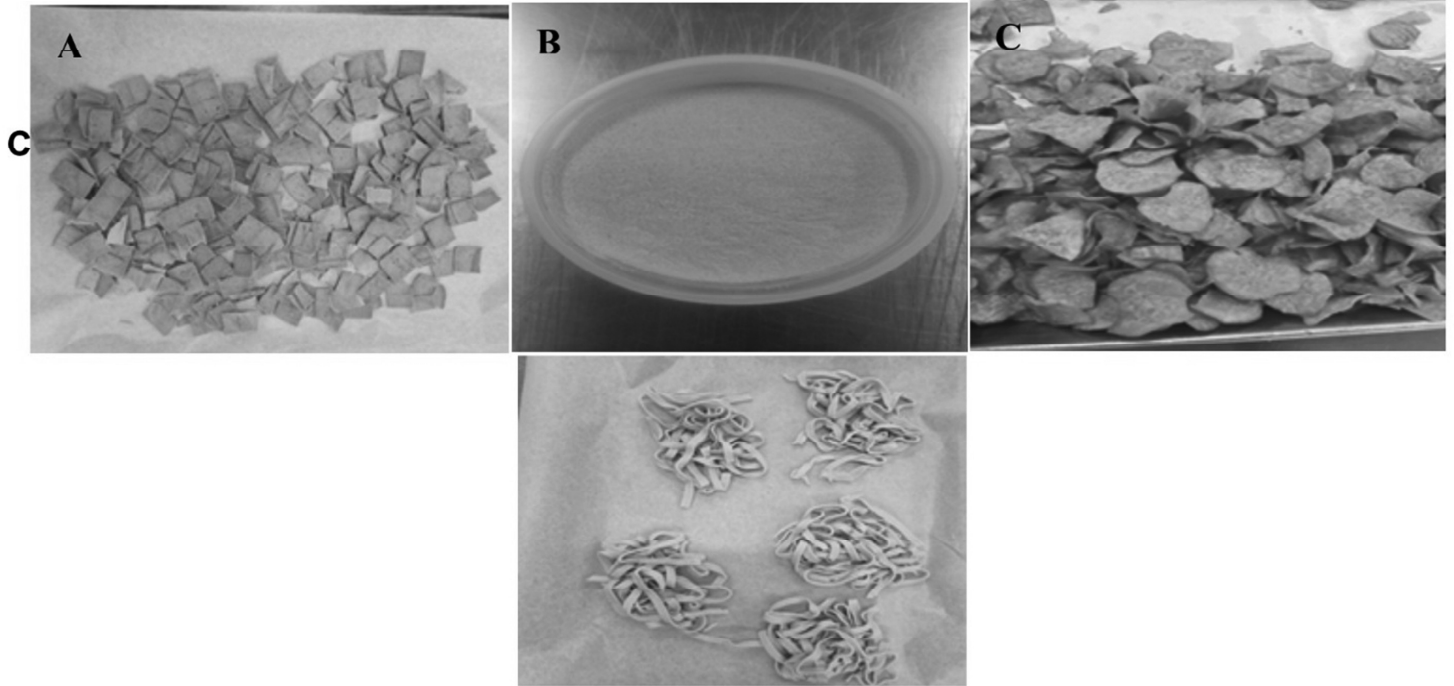


Figure 2

Representative pictures of OFSP products: (A) Flake, (B) Instant porridge, (C) Crisp and (D) Pasta