

Original Research Article

Nutritional Properties of Orange-Fleshed Sweet Potato Juice

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Abstract: Orange-fleshed sweet potato (OFSP) offers many health benefits and can be processed into different food forms including as a healthy drinking juice. However, the OFSP juice requires exploration on the juice properties, especially its nutritional elements before it can be marketed as a healthy drink. Hence, this study aims to address the detailed nutritional composition of the OFSP juice via analyses of proximate composition, amino acids, mineral, carotenoids and vitamins. Findings have shown that OFSP juice is proven to be high in beta-carotene with a value of 4916.06 µg/L which is almost 100 times the value of beta-carotene in orange juice, and also rich in vitamins, certain amino acids and minerals. By considering that, these phytochemicals can aid in the reduction of anti-mutagenic, immuno-enhancers, cancer, and free radical scavengers, in which this study has proven the potential of OFSP to be processed into a healthy juice based on its nutritional properties.

Keywords: *Ipomoea batatas* (L.) Lam; orange-fleshed sweet potato; carotenoid; healthy drinking juices

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1. Introduction

Fruits and vegetables are rich in nutrients and are considered vital for mankind which can help people who suffer from nutrient deficiency. Many people suffer from premature mortality and disability due to the low fruit and vegetable consumption (Management Association, Information Resources, 2018). In fact, inadequate fruit and vegetable intake was reported to be the cause of an estimated 3.9 million deaths worldwide in 2017 (Owolade *et al*, 2017).

Hence, proper consumption of fruits and vegetables is needed, as it can reduce the risk of cardiovascular diseases, stomach cancer, and colorectal cancer (Slavin & Lloyd, 2012). This is due to the benefits provided by many natural antioxidants that exist in fruits and vegetables. These compounds protect food from rancidity, as well as reduce oxidative damage in humans (Chiosa *et al.*, 2005). Among all the natural antioxidants, β - carotene is known for its benefits in the inhibition of initial stages of lipid peroxidation as well as play a protective role against cancer (Chiosa *et al.*, 2005).

One of the fruits and vegetables that contains high β -carotene is the orange-fleshed sweet potato (OFSP). Many studies have reported high β -carotene in OFSP, besides other nutritional elements including carbohydrate, vitamins, protein and minerals. Considering offers by OFSP, this crop holds great potential to be utilised into various food forms in various market segments. Sweet potato can be utilised to make a healthy juice, while the flesh/pulp can be used to make flour for bread and pastries which can cater to celiac disease patients (non-gluten tolerance) (Gaesser & Angadi, 2015). Detailed exploration and processing of sweet potato are needed in order to have OFSP juice to be considered as a healthy juice drink. A thorough nutrient and proximate analysis should have been performed in order to determine the potential of OFSP juice. To the best of the authors' knowledge, there is very limited information on detailed nutrient composition analysis of local sweet potato juice. Hence, this study is aimed to conduct a nutritional compositional study of the orange-fleshed sweet potato juice. Details of each nutrient are thoroughly discussed.

2. Materials and Methods

2.1. Preparation of OFSP

Fresh OFSP was purchased from the Malaysian Agricultural Research and Development Institute (MARDI) farm in Bachok, Kelantan, Malaysia. Tubers were stored in the chiller at a temperature of 10°C before the subsequent analyses. The tubers were washed with clean running tap water and finally rinsed with distilled water to remove dirt and soil before they were air-dried at room temperature. Once dried, tubers were carefully and manually peeled and cut into small pieces. The small cuts of peeled tubers were pressed using juice extractor (PSN-MJ70M, Panasonic, Malaysia) with a ratio 1:1 (w/w) of water and tuber samples. The pressed samples were ground using a wet mill (MX-SM1031S, Panasonic, Malaysia) and filtered through a cloth filter (mesh size 200) in order to separate crude juice and fibre residues prior to centrifuge (Hettich® Universal 320/320R Centrifuge, Andreas Hettich GmbH & Co. KG, Germany) for five minutes at 2500 rpm. The obtained supernatants were considered as the OFSP juice and were stored at -20°C until further analysis. The whole OFSP juice preparation steps are shown in Figure 1 below.

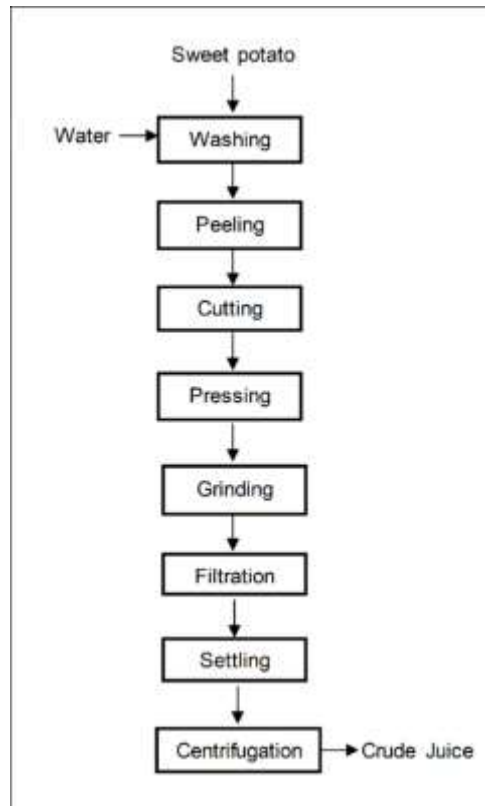


Figure 1. OFSP juice preparation steps

2.2. Proximate Analysis and Total Starch of OFSP Juice

OFSP juice was analysed for moisture content in an oven (Memmert, Germany) through the drying method at 105°C according to the procedure described in AOAC (1995). Crude fibre was determined according to AACC (2000) using Fibertec™ 2010 (Denmark). Crude fat was determined using Soxtec Extraction (Soxtec™ 2050, Denmark) for 24 hours. Crude protein content was tested by Kjeltac™ 2300, Denmark which involved protein digestion and distillation according to the Kjeldahl's method (FOSS Analytical AB., 2003). The ash was determined as a total inorganic matter by incineration of the samples at 600°C according to the method (AOAC., 1995). Total carbohydrate content was calculated by using the formula as Eq. (1):

$$\text{Carbohydrate (\%)} = 100 - (\% \text{ crude protein} + \% \text{ crude fibre} + \% \text{ total ash} + \% \text{ crude fat}) \quad (1)$$

Total energy content was obtained using Eq. (2), Atwater conversion factors 4, 9 and 4 for each gram of crude protein, crude fat and carbohydrate and expressed in calories, respectively (Dako *et al.*, 2016).

$$\text{Total energy } \left(\frac{\text{Kcal}}{100\text{g}} \right) = (9 \times \% \text{ crude fat}) + (4 \times \% \text{ crude protein}) + (4 \times \% \text{ total carbohydrate}) \quad (2)$$

Total starch content was determined by using UV-spectrophotometer (Ultrospec 3100 pro, Amershampharmacia Biotech, United Kingdom) read at 580nm (Xiao, Storms & Tsang, 2006).

2.3. Ascorbic Acid, Thiamine and Riboflavin Content

The determination of ascorbic acid was carried out by high-performance liquid chromatography (HPLC) (1100 Series, Agilent, Waldbronn, Germany). The samples were diluted with 4.5% metaphosphoric acid. Chromatographic separation was achieved on a reversed phase high-performance liquid chromatography (RP-HPLC) (Agilent ZORBAX Eclipse Plus C18, Munich, Germany) column through isocratic delivery of a mobile phase (A/B 33/67; A: 0.1M potassium acetate, pH = 4.9, B: acetonitrile: water [50:50]) at a flow rate of 1 mL/min. UV absorbance was recorded at 254nm at room temperature.

Then, thiamine and riboflavin content were determined by RP-HPLC column (Agilent ZORBAX Eclipse Plus C18, Munich, Germany; 250 × 4.6mm; 5 μm) through the isocratic delivery mobile phase (A/B 33/67; A: MeOH, B: 0.023M H₃PO₄, pH = 3.54) at a flow rate of 0.5 mL/min. Ultraviolet (UV) absorbance was recorded at 270nm at room temperature.

2.4. Total β-carotene Content

The β-carotene determination was carried out by dissolving samples in 95% (v/v) acetone. The supernatant was filtered using filter paper (Whatman filter paper grade 1) before being read with UV-Vis spectrophotometer at absorbance of 449nm (Biswas *et al.*, 2011). The concentration of β-carotene can be calculated using Beer-Lambert law as in Eq. (3):

$$A = \epsilon c l \quad (3)$$

Where A is the absorbance; c represents the concentration of carotene; ε is extinction coefficient; l is the thickness of cuvettes (path length) 1 cm; the ε of β-carotene extract using acetone is 134 × 10³ Lmol⁻¹cm⁻¹, while 536.88 g/mol of β-carotene molecular weight.

2.5. Determination of Amino Acids Content

A 10 mL HCl (6 mol L⁻¹) in acid hydrolysis tubes with air elimination by nitrogen-blowing at 110°C for 24h was hydrolysed with 160 mL of sample. The hydrolyte was diluted with ultrapure water to 50 mL after cooling, filtering and washing processes. Then, 1 mL diluent was placed in a bottle, dried with nitrogen flow and redissolved with 1 mL HCl (0.02 mol L⁻¹). For further analyses, the solutions were passed through 0.02-mesh

filter membranes. The amino acid composition of the samples was measured using amino acids automatic analyser (L-8900, Hitachi Ltd., Tokyo, Japan).

2.6. Determination of Mineral Elements Content

0.25 mL of sample was measured into a polytetrafluoroethylene digestion tube and 8 mL 65% (v/v) HNO₃ was added for pre-digestion. After 1 hour, 30% (v/v) H₂O₂ was added and digested using a microwave digestion system (MARS 5, CEM Co., Matthews, NC, USA). The digested solution was diluted to 100 mL with Milli-Q water (Bedford, MA, USA) and stored in plastic tubes at 4°C for further analysis. Inductively Coupled Plasma Mass Spectrometry (ICP-MS, 7700X; Agilent, USA) was used to measure twelve mineral elements at the operating conditions as such; cooling gas flow rate, 1.47 L/min; radio frequency power, 1280 W; auxiliary gas flow rate, 1 L/min, carrier gas flow rate, 1 L/min; nebulization chamber temperature, 20°C; and sampling depth, 8 mm.

3. Results

3.1. Proximate Analysis

Table 1 displays the proximate properties of OFSP juice. For the purpose of comparison with a more established fresh juice, the properties of orange juice reported by Yarkwan & Oketunde, (2016) are also being listed in Table 1. Based on Table 1, the moisture content of OFSP was recorded at 89.76%, almost similar to orange juice, indicating that OFSD juice in this study is comparable with the more established juice.

The crude fibre content of OFSP juice is displayed in Table 1. According to Table 1, the crude fibre content of OFSP juice was more than 175 times higher (3.49%) as compared to orange juice (0.02%). This finding shows the potential of OFSP juice to be promoted as a healthy drink since high fibre drink can be a source of energy for the human body while preventing constipation and reducing heart disease and diabetes (Rose & Vasanthakaalam, 2011; Alam *et al.*, 2016). Meanwhile, the crude fat of OFSP juice content was recorded as 1.13%, ten times higher than orange juice (0.120%) as shown in Table 1. This finding is in contrast with another study on the fat content of SP tuber which was reported at 0.2% (Alam *et al.*, 2016), that might be due to the properties alteration by processing variation.

Based on Table 1, the crude protein content of OFSP juice is 0.39% which is close to the protein content in orange juice (0.35%). The presence of protein in the OFSP juice signifies the existence of valuable essential amino acids which are important for the metabolism process in the human body. Hence, this could justify the potential of the OFSP juice as a healthy juice. Ash content of OFSP is shown as 0.68% (Table 1), much lower than orange juice in a range of 0.040–0.045%. This high value of ash content indicates a good measure of minerals preserved in juices (Rose & Vasanthakaalam, 2011). Low ash content in OFSP juice might be attributed to the solids extraction and processing process performed on the tubers during the samples preparation (Figure 1).

The total carbohydrate content of OFSP juice was determined at 5.04% which also reflects its energy content of 29.45 Kcal/100 g (Table 1). The carbohydrates are an important source of energy in human diets comprising some 40–80% of total energy intake (FAO/WHO, 1998). An optimum diet for all ages (except for children under the age of two) should consist of at least 55% of total energy from a variety of carbohydrate sources (FAO/WHO, 1998). In comparison, orange juice has a higher total carbohydrate and energy content. Nevertheless, OFSP juice can still provide energy supply for the human diet. This is proven by the amount of starch content of OFSP juice which is at 1.27% (Table 1). High starch content in the juice can be manipulated in many food applications such as for dessert and beverages.

Table 1. Proximate analysis of fresh juice.

Proximate Analysis	OFSP juice	Orange juice
Moisture (%)	89.76 ± 0.11	86.00 - 86.50
Crude Fibre (%)	3.49 ± 0.19	0.020
Crude Fat (%)	1.13 ± 0.03	0.120
Crude Protein (%)	0.39 ± 0.03	0.35 - 0.39
Ash (%)	0.68 ± 0.02	0.040 - 0.045
Total Carbohydrate (%)	5.04 ± 0.27	13.09 - 13.56
Starch (%)	1.27 ± 0.11	-nd-
Total Energy (Kcal/100g)	29.45 ± 1.07	54.84 - 56.88

*Data are mean values ± standard deviation.

3.2. Ascorbic Acid, Thiamine and Riboflavin, and β -carotene Content

Table 2 shows the vitamin composition of OFSP juice in this study as compared to orange juice reported by other studies. Based on Table 2, the OFSP juice contains 0.04 mg/100 g thiamine and 0.12 mg/100 g riboflavin reflecting the presence of vitamin B components in the juice. Vitamin B plays a role in the growth of the body as well as for lesions treatment (Ragunatha *et al.*, 2014). Meanwhile, vitamin C in the OFSP juice is 3.73 mg/100 g as shown in Table 2 which is in the lower range compared to the vitamin C in orange juice, 8 - 10 mg/100 g (Yarkwan & Oketunde, 2016). Although the value of ascorbic acid of OFSP juices is considered low, the value is still appreciable to provide health benefits to consumers. The recommended daily amount for vitamin C is 20 to 90 milligrams (mg) a day, and the upper limit is 2,000 mg a day (German Nutrition Society (DGE), 2015). Besides, the content of vitamin C in the juice might be affected by an oxidation process during the juice preparation. Interestingly, the amount of β -carotene in OFSP juice sample was 4916.06 μ g/L (Table 2), which is 92 times higher compared to orange juice ranging from 53–69 μ g/L

reported by Chiosa *et al.* (2005). This is expected as many studies have reported about the high β -carotene content in orange-fleshed sweet potato (Mamo *et al.*, 2014; Rodrigues *et al.*, 2016). β -carotene provides many health benefits such as to alleviate vitamin A deficiency which is good for children under age six (Rodrigues *et al.*, 2016). Moreover, vitamin A also helps in preventing night blindness (Alam *et al.*, 2016). By considering these benefits, OFSP juice can be promoted as a β -carotene-rich drink and can be marketed in the healthy beverages segment. The potential market of healthy beverages segment has been discussed by Mamo *et al.*, (2014), where the demand for high vitamin content drinks including β -carotene is expected to increase by 20% in the next five years. Hence, promoting OFSP juice in this segment is a wise choice.

Table 2. Vitamin composition of fresh juice.

Vitamins	OFSP juice
Vitamin B1 (Thiamine) (mg/100g)	0.04 \pm 0.18
Vitamin B2 (Riboflavin) (mg/100g)	0.12 \pm 0.03
Vitamin C (Ascorbic acid) (mg/100g)	3.73 \pm 0.06
β -carotene (μ g/L)	4916.06 \pm 0.73

*Data are mean values \pm standard deviation.

3.3. Amino acids Content

Table 3 exhibits the amino acids content of OFSP juice. Based on Table 3, histidine, arginine and aspartic content (0.50%, 0.42% and 0.20%) were recorded higher as compared to other types of amino acids. The other amino acid content such as glycine, isoleucine, alanine, lysine, glutamic, leucine, methionine, tyrosine, phenylalanine, serine, threonine and valine were found to be at lower content ranging from 0.01% until 0.09%. However, cysteine and proline were not detected from the analysis. Mohanty *et al.*, (2014) has discussed the role of each amino acid in detail including the roles of histidine in the protein interaction and is also a precursor of histamine. Besides, histidine is important for the repair of tissues and growth, for maintaining the myelin sheaths, and for the removal of heavy metals from the body. Meanwhile, arginine is needed in cell division, ammonia removal, immune function, wound healing and hormone release (Mohanty *et al.*, 2014). It also plays important roles in neurotransmission, maintenance of blood pressure and blood clotting which is the precursor for biological synthesis of nitric oxide. In addition, arginine is also essential for the recovery of a few diseases like hypertension, erectile dysfunction, sepsis, preeclampsia and anxiety. As amino acid deficiencies lead to several diseases, knowledge of its composition in foods is important as it will affect the preparation, processing and storage of foods and use as dietary guidance for healthy drink production.

Table 3. Amino acids content of juice.

Amino Acids (%)	OFSP juice
Alanine	0.06 ± 0.31
Lysine	0.05 ± 0.12
Arginine	0.42 ± 0.65
Aspartic	0.20 ± 0.88
Cystine	-nd-
Glutamic	0.09 ± 0.45
Glycine	0.04 ± 0.23
Histidine	0.50 ± 0.11
Isoleucine	0.04 ± 0.07
Leucine	0.06 ± 0.32
Methionine	0.01 ± 0.48
Phenylalanine	0.05 ± 0.01
Proline	-nd-
Serine	0.04 ± 0.17
Threonine	0.04 ± 0.05
Tyrosine	0.03 ± 0.06
Valine	0.06 ± 0.33

*Data are mean values ± standard deviation.

3.4. Mineral Element Content

Table 4 represents the mineral element composition of the OFSP juice compared to orange juice as reported by Yarkwan & Oketunde, (2016). The OFSP juice contains 147.77 mg/100 g of potassium, 30.06 mg/100 g of sodium, 10.03 mg/100 g of calcium, and 0.79 mg/100 g of iron which are higher as compared to orange juice, as shown in Table 4. The role of calcium is good for humans in particular cell physiology, mineralisation of bone and in making the teeth and bone very strong. Meanwhile, iron helps in transporting oxygen in the blood. In human diets, these minerals are important micronutrients (Danish *et al.*, 2019).

Besides, the other mineral element composition of OFSP juice such as phosphorus (44.74 mg/100 g), sulphur (32.66 mg/100 g), magnesium (32.64 mg/100 g), zinc (0.57 mg/100 g), manganese (0.31 mg/100 g), aluminium (0.30 mg/100 g), copper (0.17 mg/100 g), and boron (0.15 mg/100 g) were determined in Table 4. Subsequently, the appropriate Recommended Dietary Allowance (RDA) or adequate intake (AI), AI for females and males aged 31–50 is 1500 mg/day (sodium), 1000 mg/day (calcium) and 4700 mg/day (potassium) (Yarkwan & Oketunde, 2016; Koubová *et al.*, 2018). Iron has an RDA value of 8 mg/day and 18 mg/day for average men and women aged 31–50 respectively (Yarkwan & Oketunde, 2016; Koubová *et al.*, 2018). Thus, in reference to the AI and RDA, OFSP juice can provide high minerals to the consumers in order to cater to the required intake.

Table 4. Mineral element composition of fresh juice.

Minerals (mg/100g)	OFSP juice	Orange juice
Phosphorus	44.74 ± 0.13	-nd-
Potassium	147.77 ± 0.09	0.0181 - 0.021
Sulphur	32.66 ± 0.02	-nd-
Aluminium	0.30 ± 0.33	-nd-
Calcium	10.03 ± 0.15	0.0046 - 0.0048
Magnesium	32.64 ± 0.11	-nd-
Manganese	0.31 ± 0.46	-nd-
Iron	0.79 ± 0.04	0.0012 - 0.0014
Copper	0.17 ± 0.18	-nd-
Zinc	0.57 ± 0.01	-nd-
Boron	0.15 ± 0.03	-nd-
Sodium	30.06 ± 0.22	0.0052 – 0.0053

*Data are mean values ± standard deviation.

**Yarkwan & Oketunde, 2016

4. Conclusion

Based on the proximate analysis, vitamins, amino acids and mineral composition, OFSP juice shows a promising potential to be an alternative for a healthy drink. The highlight of the juice composition was the high content of β -carotene, which can provide many health benefits including prevent anti-mutagenic, immuno-enhancers, cancers and free radical

scavengers. Besides the vitamins, amino acids and mineral content of the OFSP juice are also considered sufficient to partly cater to the recommended daily intake of consumers.

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