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Development of Orange-Fleshed Sweet Potato (*Ipomoea batatas*) Juice: Analysis of Physico-Chemical, Nutritional and Sensory Property

Tariku Zena Mamo, Abadi Gebre Mezgebe*, Abebe Haile

Hawassa University, College of Agriculture, School of Nutrition, Food Science and Technology, Hawassa, Ethiopia

Abstract Studies indicated that orange-fleshed sweet potato (OFSP) root is a versatile food item with good nutritional importance. However this root is not utilized well in most developing countries. Developing and characterizing a new of OFSP could improve the utilization and Vitamin A intake. In the present study different OFSP-based juice products were developed through blending with ginger and mango juice: product-1 (100% OFSP), product-2 (99% OFSP & 1% ginger), product-3 (90% OFSP & 10% mango juice), product-4 (80% OFSP & 20% mango juice), product-5 (89% OFSP, 10% juice and 1% ginger), product-6 (79% OFSP, 20% mango juice & 1% ginger) and product-7 (commercial mango juice). Analysis of physico-chemical (pH, titratable acidity, total soluble solids and viscosity), nutritional (β-carotene, vitamin-C, iron, zinc, phytate, bio-availability of iron and zinc) and sensory (appearance, aroma, color, taste, mouth feel and over acceptability) properties of the products was conducted. It was shown that soluble solids, viscosity and β-carotene increased with increasing percentage of OFSP. Products flavored with ginger had lower pH, higher acidity and ash, enhanced taste aroma. Moreover, products flavored with mango juice had lower soluble solid and viscosity, better vitamin-c, taste, aroma, mouth feel, color and appearance. The phytate and bioavailability of iron and zinc was at acceptable range in ginger containing products. Generally, products contained both ginger and mango juice had better physico-chemical, nutritional sensory acceptability. In development of orange-fleshed sweet potato juice combinations of ingredients should be considered to improve overall quality and stability of the products.

Keywords Orange-fleshed Sweet Potato, Juice, Blending ratio, Physico-chemical, Nutritional content, Sensory property

1. Introduction

Orange-fleshed sweet potato is seasonal crop, perishable that cannot be stored for long period of time unless preserved in some way. Orange-fleshed sweet potatoes are rich in dietary fiber, minerals, vitamins, and antioxidants, such as phenolic acids, anthocyanins, tocopherol and β-carotene. They are good source of vitamin-A, vitamin-C, B-vitamins (B_2, B_3, and B_6), potassium and copper [20, 29, 47, 48]. Numerous nutritious food products could be developed from the nutritionally rich orange-fleshed sweet potato and other supplementary food sources [2, 16]. It has been stated that chips, cookies, breads, alcoholic and non-alcoholic beverage can be developed from OFSP with or without flavoring with fruit juices and spices [17, 33, 38, 43, 51].

Ahmad *et al.* [4], Bengtsson *et al.* [13], Chun [15], and Coronel *et al.* [16] stated that the occurrence of changes of nutritional value of sweet potato roots during preparation and processing. Similar reports described that processing during product development may induce alteration of physico-chemical, nutritional and organoleptic properties [5, 15, 16, 30, 39, 41]. Effects of processing and cooking documented by Avula [11], Grabowski [23] and WHO [50] reported reduced total carbohydrate (from 43 to 29.4%), protein (from 1.6 to 0.95%), ash (from 1.3 to 0.9%), fiber (17.5 to 0.06%), dry matter (from 9.2 to 8.69%), no change in fat and increased moisture (from 27.4 to 60%). Cooking process may reduce vitamins (β-carotene, vitamin-C…) and minerals (Ca, P, Zn, Fe, Mn…) of sweet potato due to degradation and leaching [11]. The extent of loss will depend on the cooking method, temperature and time. However, the positive advantage of cooking improves digestibility and availability of nutrients and promotes palatability and shelf-life of the food [11, 23]. Bioavailability refers to the proportion of a nutrient that is absorbed from diet and used for body functions [19, 22, 31]. It can be influenced by food matrix and chemical form of the nutrient. In addition to the in-vitro and in-vivo methods [22, 19], bioavailability of minerals can also be determined using molar ratio of anti-nutritional factors (phytate, tannin, oxalate…) to the respective minerals (iron, zinc, calcium, magnesium and

* Corresponding author:
abadigbr46@gmail.com (Abadi Gebre Mezgebe)
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sodium…) [1, 3, 21, 24].

Production of OFSP beverage is not mixing up of recommended flavoring and preservatives, a certain bio-chemical and physical changes are taking place during processing [11, 28]. The major change is enzyme catalyzed degradation of starch into simple sugars (saccharification) [11]. Malt has been used as a source of both proteolytic and diastatic enzymes [26]. The enzymes that become active during mashing OFSP into juice are α-amylase and β-amylase. According to Mills [33] and Serrat *et al.* [41] the enzymes work together to break down long complex chains of soluble starch molecules into simple sugars or dextrins with optimum temperature. During development of OFSP beverage, the mashed juice must not be exposed to alcoholic fermentation. This can be obtained by pasteurizing and packing to prevent growth of alcoholic fermentation bacteria, yeast and other spoilage micro-organism.

Considering the nutritional importance of OFSP, current limitation its utilization due to seasonal production perishablity, sub-optimum storage technology [10, 12, 27]; The need for intervening vitamin A deficiency in most developing countries [44, 45, 48, 49]; which is affecting around significant number of children 6-59 months of age and mothers [34]; This research aimed at development of OFSP juice flavored with mango and ginger and analysis of physico-chemical, nutritional and sensory properties of the products. pH, total soluble solids, titratable acidity and viscosity were considered as indicators of physico-chemical, while *β*-carotene, vitamin-C, iron, zinc, phytate, bio-availability of iron and zinc in molar ratio as nutritional indicators and acceptability test like appearance, aroma, color, taste, mouth feel and over acceptability.

2. Materials and Methods

2.1. Sample Preparation

OFSP *(Ipomoea batatas)* locally called Kulfo variety was collected from Areka Agricultural Research Center, Southern Ethiopia. Mango *(Mangifera Indica)*, ginger *(Zingiber officinale)* and maize (*Zea mays*) were purchased from local market. The OFSP roots were sorted-out, weighed, washed, peeled with mechanical potato peeler and cut into smaller pieces by stainless steel knife. Then it was rinsed with tap water, chopped and homogenized using cutter-mixer. Additional water (2 liter /kg of OFSP) and 5% maize malt flour was added. To prepare the malt flour (as source of β- and α-amylase enzymes), the maize was cleaned, washed and steeped for 24 hour and sprouted for 3 days on a jute sac, sun dried for 3 days and grinded and screened with 0.15mm screen opening [41]. The mixtures (homogenized OFSP, water and malt) were heated to a temperature of 60°C for 1 hour. The temperature was then being raised to 70°C for another 1 hours until complete degradation of starch took place. Degradation of starch was confirmed by iodine test (complete disappearance of blue black color of starch upon addition of potassium iodide reagent). The mixture was filtered with muslin clothe. The juice extract was pasteurized by rising the temperature of stove to 90 °C for 10 minute and bottled hot. The bottled juices were cooled down at ambient temperature and stored in refrigerator at 3 °C until analysis [51].

Different OFSP juice products were developed based on a formulations: Product 1 (100% OFSP), Product-2 (99% OFSP & 1% ginger), Product-3 (90% OFSP & 10% mango juice), Product-4 (80% OFSP & 20% mango juice), Product-5 (89% OFSP, 10% mango juice and 1% ginger), and Product-6 (79% OFSP, 20% mango juice & 1% ginger). Mango juice was extracted by cooking mango fruit for 20 minutes at 60°C temperature and pulped by stainless steel blade. The mango juice was weighed and added into cooking media before 30 minutes to complete cooking. Ginger was prepared by peeling and grinding using laboratory pestle and mortar and it was added in the same way as mango juice.

2.2. Physico-Chemical Properties Analysis

2.2.1. pH

pH of the developed products was measured after calibrating a pH meter with pH 4.0 and pH 7.0 standard buffer solution (ready to use). Sample beverage of 100 ml was acquired in 250 ml beaker and 1/3 of pH electrode was immersed in to the beaker containing sample. Finally, pH of each juice product sample was measured in triplicate and recorded [8].

2.2.2. Titratable Acidity (TA)

Titratable acidity of the juices was determined using method of AOAC [8]. The beverage was thoroughly mixed and filtered using muslin cloth. About 5 ml of filtrate was dissolved in distilled water until the volume was reached 50 ml. Then 5 ml aliquot of sample solution was taken and titrated with 0.1N NaOH using phenolphthalein solutions as indicator till the orange color of the beverage sample was changed into pink. Triplicate measurement was taken and calculated as percent of citric acid using the equation 1.

$$Acidity(\%) = \frac{Vol.NaOH \times 0.64 \times conc.NaOH}{Sample.Weight} \quad (1)$$

2.2.3. Total Soluble Solids (TSS)

The concentration of dissolved sugars was determined using Refractometer as addressed in AOAC [7] method. After calibrating with distilled water, 2 drops of sample was introduced on the prism and allowed the temperature to be stabilized at 20°C and triplicate measurement was taken from the Refractometer. Result was expressed as ^{o}Brix (the amount of total dissolved solids in 100 g of juice product).

2.2.4. Measuring Viscosity

As described in AOAC [8], the viscosity of the beverage samples was determined using Ubbelohde-type viscometer.

After maintaining the viscometer vertically, Sample was transferred into sample holder tube. The viscometer was placed in a thermostatic water bath maintained at temperature of 24°C and allowed to stand for 20 minutes. After closing sample holder tube, the sample was transferred to measuring tube by suction. When the sample starts to flow down from the lower end of capillary tube, the time (seconds) (t) required for the sample to pass through the capillary tube was measured and viscosity (v) was calculated using equation 2. k is the kinematic viscometer constant, determined from distilled water.

$$V = k \times t \tag{2}$$

2.3. Nutritional Content Determination

2.3.1. β-carotene

The content of β-carotene of the samples was determined according to the AOAC [8]. About 40 ml sample was taken into 1000 ml beaker and 20 ml of acetone was added. The addition of acetone was continued until the beverage was saturated and weight is then recorded. The sample was covered and stored in refrigerator overnight. All aqueous layers were extracted by using pipette and discarded while the remaining content was weighed and recorded. All of water contained in the sample was filtered using a filter funnel and filter paper and the solid substance remained was placed in another beaker and 20 ml of acetone was added. About 15 g mixed sample was weighed and placed in a filtration funnel. Then 2 ml of acetone and 15 ml of CH_2Cl_2 was added to facilitate solubility and filterability and the mixture was filtered with vacuum filtration method. The CH_2Cl_2 was removed and 3 drops of $CaCl_2$ was added to enhance the complexation of organic compounds. The samples were taken into weighed and moderately heated vials. Petroleum ether (1 ml) was added and further purified by column chromatography where small piece of cotton was placed on a layer of sand, a layer of a mixture of silicone gel and hexane in a glass pipette. Air was pumped into the content to seal off hexane, sand and petroleum ether. β-carotene substance and hexane were was captured in a test tube as set aside. In the UV-VIS spectrophotometric detection, the absorbance at 450nm was read in quartz cells. Reading was taken quickly, since petroleum ether is a volatile solvent. The ß-carotene concentration (C in $mg.l^{-1}$) was calculated using Lambert Beer law from measured data of the absorbance as indicated in the equation 3.

$$C = \frac{10^3 \times MA}{L\xi} \tag{3}$$

Where, C is the concentration of ß-carotene, ξ is the Molar extinction coefficient for β-carotene in Petroleum ether ($138900 L.mol.^{-1}.cm^{-1}$), M is the molecular weight of β-carotene ($536.88 g.mol^{-1}$) and L is the path length (generally equal to 1cm).

2.3.2. Vitamin-C

The dye-titration method described by AOAC [8] procedure was used to determine the concentration of vitamin-C. Metaphosphoric acid extracts of the beverage was prepared and pH was adjusted to 1.2. The reducing capacity of the extracts was measured by titrating with 2, 6-dichlorophenolindophenol (DCIP). In this oxidation-reduction reaction test, ascorbic acid in the extract is oxidized to Dihydro Ascorbic acid (DHAA) and the indophenol dye was reduced to a colorless compound. End point of the titration was detected when excess of the unreduced dye gave a rose pink color in acid solution. The concentration of vitamin-C was determined from balanced chemical equation as described by AOAC [8].

2.3.3. Ash

The AOAC [7] method was considered for determining the percentage of ash. About 15 gram of homogenized juice sample was placed on a crucible and dried in oven at 105°C for 3 hours. The dried sample was then charred using hot plate at 350°C till it ceased to smoke. The charred sample was then ashed in a muffle furnace at 550°C overnight. The weight of ash was measured using analytical balance. The ash content of the samples was calculated using the equation 4.

$$Ash(\%) = \frac{W3 - W1}{W2 - W1} \tag{4}$$

Where, W1 is the weight of crucible, W2 is weight crucible containing beverage sample before ashing, and W3 is weight of crucible containing ashed beverage sample.

2.3.4. Analysis of Zinc

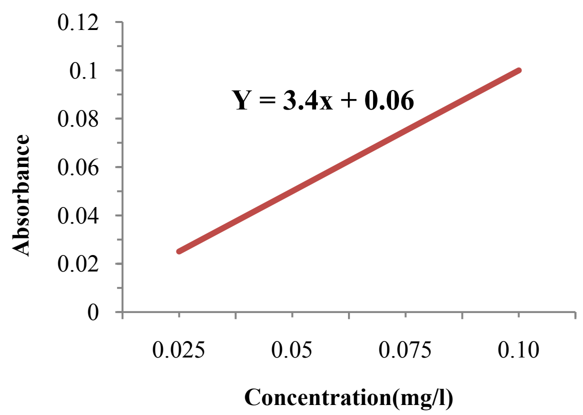

Figure 2.1. Calibration Curve for Determination of Zinc

Foremost, ash was prepared and treated with a concentrated hydrochloric acid, transferred to a volumetric flask and made up to 50 ml. An aliquot of the ash solution was used for analysis of zinc by the Atomic Absorption Spectrophotometer (AAS). For AAS the wavelength was set to 213.9 nm. Zinc concentration of samples was determined using standard calibration curve plotted using standard concentrations of zinc solution (0.025 mg/l, 0.05 mg/l, 0.075 mg/l, and 0.1mg/l) prepared within the analytical range and the corresponding absorbance. Concentrations of zinc in test samples were calculated from the calibration curve plotted as stated in AOAC [9].

2.3.5. Analysis of Iron

Determination of iron concentration was conducted according to AOAC [9]. Preparation and treatment of ash to determine iron concentration using AAS method was the same as the zinc determination. However, for iron determination the wavelength was set to 248.3 nm. Ferric nitrate solution for atomic absorption spectrophotometer was used as standard. The standard calibration curve was prepared using known concentrations of ferric nitrate solution (0.02 mg/l, 0.04 mg/l, 0.06 mg/l, 0.08 mg/l and 0.1 mg) which are within the analytical range and plotted with the corresponding absorbance. A concentration of iron content of the samples was calculated from calibration curve.

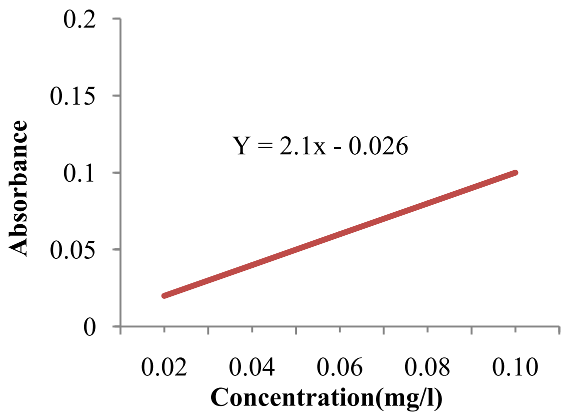

Figure 2.2. Calibration Curve for Determination of Iron

2.3.6. Phytate

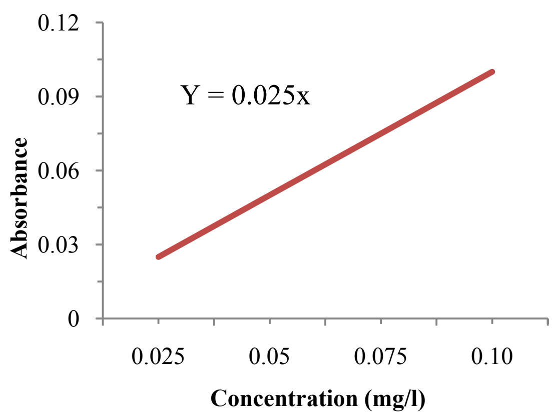

Figure 2.3. Calibration Curve for Determination of Phytate

Phytate content of the samples was determined according to AOAC [9]. About 0.1 g of juice sample was extracted with 10 ml of 2.4% HCl in mechanical shaker for 1 hour at an ambient temperature and centrifuged at 3000 rpm for 30 min. About 1 ml of Wade reagent (containing 0.03% solution of $FeCl_3.6H_2O$ and 0.3% of sulfosalicilic acid in water) was added to 3 ml of the sample solution (supernatant from the centrifuge) and the mixture was mixed on a vortex mixer for 5 seconds. Four different concentration of standard sodium salt of phytate (0.025 mg/l, 0.05 mg/l 0.075 mg/l and 0.1mg/l) were prepared to determine the calibration curve and 0.15 g of standard solution was added into 15 ml of centrifuge tubes with 3 ml of water which were used as a zero level (blank). 1ml of the wade reagent was added to each test tube and the solution was mixed on a vortex mixer for 5 seconds. The mixture was centrifuged for 10 minutes and the absorbances of the solutions (both sample and standard) were measured at 500 nm using deionized water as blank in UV-Vis spectrophotometer. The concentration of phytate in the juice sample was determined from the calibration curve.

2.3.7. Bioavailability

Bioavailability of minerals (zinc and iron) was determined by molar ratio. The mole of phytatic acid and minerals was determined by dividing the weight of phytatic and minerals with their respective atomic weight (Phytate: 660 g/mol; Fe: 56 g/mol; Zn: 65 g/ mol). The molar ratio with respect to phytate was obtained by dividing the mole of phytate with the mole of respective minerals [35]. Equation 5 and 6 was used to calculate the bioavailability iron and zinc with molar ratio.

$$Phytate : Iron = \frac{Mol.Phytate}{Mol.Iron} \quad (5)$$

$$Phytate : Zinc = \frac{Mol.Phytate}{Mol.Zinc} \quad (6)$$

2.4. Sensory Evaluation

Sensory acceptability of the products was evaluated by panelists based on their voluntariness to participate in the evaluation [46]. Sensory attributes of the juice products like appearance, taste, aroma, mouth feel, color, and over all acceptability were evaluated by the panelists. Five point hedonic scales (1= Dislike very much, 2= Dislike, 3= neither like nor dislike, 4 = Like and 5= Like Very much) was used. Each panelist was sat in isolated place to limit any disturbances. Coded juice samples were presented in tea glass and allowed to be assessed twice in duplicate test results.

2.5. Data Analysis

Data were statistically analyzed by the help of SAS 9.0 using one way analysis of variance (ANOVA). List significant differences were calculated at $p < 0.05$. After analysis of data, mean comparison was made for all the significant treatments and mean ± standard deviation is presented in the tables of results.

4. Results and Discussion

4.1. Physico-Chemical Properties

As shown in Table 4.1 Different formulations employed for the development of OFSP juice resulted in variation of physico-chemical properties (pH, TA, TSS, viscosity) significantly at $p< 0.05$ for some juice products. The pH values for the developed OFSP products varied from 3.92±0.056 to 5.19±0.055. All developed juices products had pH value less than 5.5 (acidic in nature) [9]. Product 4 contained highest pH value whereas product 7 contained lowest pH. There was no significant difference between pH values of Product 3 & 6, 4 & 6, and 3 & 5. Next to product 7, product 2 (1% ginger & 99% OFSP) had pH lower than the others. The lowest pH value could be attributed to the addition of ginger that has more organic acid contents [17]. The highest pH in product 4 could be due to the mango juice added, lower organic acid content of mango that could brought change in pH than ginger. The lowest score of pH of product 7 might be due to the preservatives used. The work of Wireko [51] is in line with the findings of the present study. During developing OFSP juice mechanisms to reduce pH should be considered for better microbial stability; low pH is important to inhibit microbial growth in juices [42].

The TA values of developed products varied from 0.012±0.002 to 0.058±0.047. There was no significant difference between product 2 & 7, and 3 & 6. The highest value was recorded for product 7 while the lowest TA value was recorded for product 4. The highest value of TA for product 2 can be attributed to the addition of ginger, which has more organic acid (% citric acid) content [18]. As compared to ginger flavored products, mango flavored products had lower TA value (as ginger have more organic acid than mango). The highest value TA scored for product 7 might be due the preservatives added to the product for commercial purpose. The TA analyzed by Wireko [51] are also consistent with the finding this study. According to Mei *et al.* [32] explanation, TA is very important to inhibit microbial growth and the TA of the OFSP products should be considered for microbial stability.

TSS varied ranging from 13.65±0.064 to 20.91±0.48 °Brix. The TSS of product 2, 3, & 4 was not significantly different as well as between product 4 & 5. Product 1 contained the highest TSS but product 7 contained the lowest TSS value. Even though all of juice products were formulated with 10% of sugar, almost half of TSS came from degradation of starch of OFSP in to simple sugars by action of amylase enzyme obtained from malt added during juice preparation [41]. The highest TSS content of product 1 is due to high amount of carbohydrate (29.4%) of OFSP in the form of starch and the conversion of the starch into simple sugars as explained by Dansby *et al.* [17]. Next to product 1, product 2 had also high value of TSS content. Product 2 was blended only with 1% ginger and 99% of OFSP. The lowest TSS value 15.98 °Brix belongs to product 6 and this can be attributed to the relatively low percent of OFSP (79%) used during preparation. Osman [37] obtained consistence results that support the current findings.

The viscosity of juice products ranged from 61.35±3.51cp to 141±3.21 cp depending on the bases of product formulation. No significant difference existed among product 4, 5 and 6. The highest viscous product was product 1 whereas product 7 was the lowest. Viscosity is the resistance property of the juice to flow [6]. The highest viscosity in Product 1, could be due to high content of starch as it contains 100% OFSP, juices developed from OFSP are naturally viscous and thicker than other juices prepared from fruit and vegetable [37]. Even though starch contained in OFSP was converted in to other simple sugars, it was observed that the developed products had high TSS and thickness. When percent of OFSP decreased for the product preparation, viscosity of the juice product was decreased too. Next to product 1, product 2 had high viscosity (112±5.85 cp) this is due to content of OFSP (99%). Product 3 was also relatively viscous as compared to the other products (Product 4, 5, 6 & 7). The low viscosity result of the products (Product 4, 5, 6 & 7) can be attributed to the low content of OFSP used in the formulation.

Table 4.1. Physico-chemical Properties of Juice Products

Products	pH	TA (%)	TSS (°Brix)	Viscosity (cp)
Product 1	$4.58±0.037^{d}$	$0.026±0.002^{b}$	$20.91±0.48^{a}$	$141±3.21^{a}$
Product 2	$3.92±0.056^{e}$	$0.057±0.004^{a}$	$18.41±1.17^{b}$	$112±5.85^{b}$
Product 3	$5.13±0.045^{bc}$	$0.016±0.001^{cd}$	$18.24±0.44^{b}$	$89±3.05^{c}$
Product 4	$5.19±0.056^{a}$	$0.012±0.002^{d}$	$17.44±0.42^{bc}$	$80±2.08^{d}$
Product 5	$5.07±0.047^{c}$	$0.019±0.001^{c}$	$17.12±0.47^{c}$	$77±3.00^{d}$
Product 6	$5.14±0.055^{ab}$	$0.017±0.001^{cd}$	$15.98±0.03^{d}$	$72±3.05^{de}$
Product 7	$3.57±0.047^{f}$	$0.058±0.005^{a}$	$13.65±0.06^{e}$	$61±3.51^{f}$

Product 1: 100% OFSP (control), Product 2: 99% OFSP +1% ginger, Product 3: 90% OFSP +10% mango, Product 4: 80% OFSP +20% mango, Product 5: 89% OFSP +1% ginger+10% mango, Product 6: 79% OPSP + 1% ginger+20% mango, Product 7: commercial juice. Means ±STDEV with the different letter of superscripts in a column are significantly different ($p< 0.05$).

4.2. Nutritional Analysis

4.2.1. Vitamin and Mineral Contents

The content of nutrients such as β-carotene, vitamin-C, ash, iron and zinc is presented in Table 4.2. Results varied significantly at $p<0.05$ for some juice products depending on formulation. β-carotene contents of the products varied from 0.0092±0.0006 mg/l to 0.192±0.003 mg/l. The highest value of β-carotene was contained in product 1 whereas product 7 contained lowest value. There was no significant difference between β-carotene content of product 4 & 5, and 5 & 6. The highest β-carotene recorded in product 1 and product 2 is due to higher amount of β-carotene in OFSP than when ginger and mango fruit are included. There is no evidence for the presence of β-carotene in ginger but product 2 had higher β-carotene content than others except product 1. Next to product 2, product 3 scored higher β-carotene that can still be attributed to the content of OFSP. Lowest value of β-carotene was measured in product 6 due to low OFSP (79%) and low β-carotene in mango juice. The result of this study is inconsistent with the WHO [50], Avulla [11] and Grabowski [23] which reported more than 10 folds β-carotene for cooked OFSP. Two possible reasons could be mentioned; first the juice product was cooked for 2 hours at the temperature of 60-70°C and during this time β-carotene might be degraded and lost in the final product [23]. The second major reason is the insolubility of β-carotene in water, thus β-carotene does not dissolve in water but slightly soluble in alcohol, fat, oil and soluble in organic solvents like ether [25]. Wireko [51] obtained 0.0458 mg/100g β-carotene for juice prepared from OFSP and which is in the range of this current study results.

The vitamin-C values for the juices varied from 0.13±1.61 mg/l to 93.75±4.21 mg/l. the vitamin-C values of product 3 and 5 were not significantly different. Product 7 contained the highest vitamin C content while product 1 contained lowest. The lowest vitamin-C of product 1 observed could be due to the cooking at the temperature 60-70°C for 2 hours which might resulted in loss of originally available vitamin-C in OFSP [23]. Even though equal amount of ascorbic acid was added, results of vitamin-C varied significantly depending on the proportion of the ingredients. Next to product 7, the highest vitamin C (86.96±2.68 mg/l) was recorded for product 4. This is due to 20% mango juice added which contains significant amount of vitamin-C [50] as well as the mango juice was added at the end of cooking which could avoid vitamin-C loss [23, 50]. The lowest value of vitamin-C (66.12±2.90 mg/l) next to product 1 was contained in product 2, this can be explained by the low amount of Vitamin-C found in both OFSP and ginger. Generally mango flavored juice products had relatively better vitamin-C content [23, 52].

Table 4.2. Vitamins and Minerals Content of OFSP-based Juices

Products	β-carotene(mg/l)	Vit-C (mg/l)	Ash (%)	Zinc (mg/l)	Iron (mg/l)
Product 1	0.192 ±0.003 ^{a}	0.13 ±1.61 ^{f}	0.86 ±0.04 ^{b}	0.074 ±0.005^{c}	0.147 ±0.01 ^{bc}
Product 2	0.082 ±0.012 ^{b}	66.12 ±2.90 ^{e}	1.12 ±0.03 ^{a}	0.103 ±0.004^{b}	0.154 ±0.05 ^{b}
Product 3	0.05 ±0.003 ^{c}	72.02 ±0.30 ^{d}	0.79 ±0.04 ^{c}	0.057 ±0.004^{d}	0.161 ±0.02 ^{b}
Product 4	0.038 ±0.002 ^{d}	86.96 ±2.68 ^{b}	0.166 ±0.025 ^{f}	0.045 ±0.025^{e}	0.093 ±0.07 ^{e}
Product 5	0.033 ±0.001 ^{de}	70.77 ±1.40 ^{d}	0.94 ±0.035^{b}	0.91 ±0.004^{b}	0.28 ±0.02 ^{a}
Product 6	0.027 ±0.004 ^{e}	77.71 ±2.38 ^{c}	1.07 ±0.02 ^{a}	0.068 ±0.004^{c}	0.12 ±0.02^{cd}
Product 7	0.0092 ±0.000 ^{f}	93.75 ±4.21 ^{a}	0.67 ±0.052^{d}	0.0085±0.001 ^{f}	0.296 ±0.03 ^{a}

Product 1: 100% OFSP (control), Product 2: 99% OFSP +1% ginger, Product 3: 90% OFSP +10% mango, Product 4: 80% OFSP +20% mango, Product 5: 89% OFSP +1% ginger+10% mango, Product 6: 79% OPSP + 1% ginger+20% mango, Product 7: commercial juice. Means ±STDEV with the different letter of superscripts in a column are significantly different ($p< 0.05$).

Table 4.3. Phytate and Bioavailability of Iron and Zinc

Products	Phythate (mg/l)	Molar ratio (Phytate/Fe)	Molar ratio (Phytate/Zn)
Product 1	0.00 ^{d}	0.00 ^{d}	0.00 ^{d}
Product 2	0.0035±0.0014 ^{a}	0.0031±0.00014 ^{b}	0.00049±0.00015 ^{c}
Product 3	0.00 ^{d}	0.00 ^{d}	0.00 ^{d}
Product 4	0.00 ^{d}	0.00 ^{d}	0.00 ^{d}
Product 5	0.0023±0.0014 ^{b}	0.0042±0.00012 ^{a}	0.00073±0.00015 ^{a}
Product 6	0.0012±0.0006 ^{c}	0.0029±0.00015 ^{c}	0.00054±0.0003 ^{b}
Product 7	0.00 ^{d}	0.00 ^{d}	0.00 ^{d}

Product 1: 100% OFSP (control), Product 2: 99% OFSP +1% ginger, Product 3: 90% OFSP +10% mango, Product 4: 80% OFSP +20% mango, Product 5: 89% OFSP +1% ginger+10% mango, Product 6: 79% OPSP + 1% ginger+20% mango, Product 7: commercial juice. Means ±STDEV with the different letter of superscripts in a column are significantly different ($p< 0.05$).

Table 4.4. Sensory Evaluation of OFSP-based Juices

Products	Appearance	Aroma	Color	Taste	Mouth feel	Overall acceptability
Product 1	2.86 ±0.58^{e}	3.62 ±0.67^{e}	2.79 ±0.56^{g}	4.10 ±0.57^{b}	3.72 ±0.59^{e}	3.45 ±0.56^{e}
Product 2	3.00 ±0.63^{d}	4.35 ±0.71^{b}	2.94 ±0.63^{f}	3.97 ±0.71^{c}	4.00 ±0.58^{c}	3.87 ±0.63^{d}
Product 3	3.23 ±0.77^{d}	4.16 ±0.69^{c}	3.33 ±0.71^{e}	3.80 ±0.71^{d}	3.90 ±0.60^{cd}	3.97 ±0.71^{c}
Product 4	3.66 ±0.67^{c}	4.17 ±0.84^{c}	3.76 ±0.63^{c}	3.86 ±0.83^{d}	3.86 ±0.79^{d}	3.97 ±0.64^{c}
Product 5	3.52 ±0.72^{c}	3.72 ±0.69^{d}	3.65 ±0.71^{d}	3.97 ±0.75^{c}	4.13 ±0.67^{b}	4.06 ±0.70^{c}
Product 6	3.79 ±0.63^{b}	4.46 ±0.62^{a}	4.00 ±0.65^{b}	4.17 ±0.71^{b}	4.13 ±0.65^{b}	4.28 ±0.65^{b}
Product 7	4.58 ±0.56^{a}	4.42 ±0.56^{a}	4.68 ±0.47^{a}	4.35 ±0.66^{a}	4.52 ±0.65^{a}	4.55 ±0.47^{a}

Product 1: 100% OFSP (control), Product 2: 99% OFSP +1% ginger, Product 3: 90% OFSP +10% mango, Product 4: 80% OFSP +20% mango, Product 5: 89% OFSP +1% ginger+10% mango, Product 6: 79% OPSP + 1% ginger+20% mango, Product 7: commercial juice. Means ±STDEV with the different letter of superscripts in a column are significantly different ($p < 0.05$).

As shown in Table 4.2, the ash of products ranged from 0.166±0.025 mg/l to 1.12±0.03 mg/l. Product 7 contained the lowest ash content whereas product 2 contained highest. According to WHO [50] ash is the inorganic residue after water and organic matter have been removed by heating in the presence oxidizing agent, which provides the total measure of minerals in the products. The highest ash in product 2 could be due to the ginger added which contains comparatively higher ash than mango and OFSP. Next to product 7, the lowest ash content recorded for product 4 could be due to the mango juice added (20%) contains lower percent of ash [11]. There was no significant difference existed between product 2 & 6, and Product 1 & 5. The reason could be due to the less amount of ash in OFSP and the addition of 10% mango juice contributed to have equivalent percent of ash in both products.

The zinc content of the products varied from 0.0085±0.0005 to 0.103±0.0041 mg/l. Product 2 contained high zinc content whereas product 7 contained the lowest. The highest value of zinc in product 2 is due to the addition of ginger as it relatively contains higher amount of zinc [50]. Next to product 7, the lowest value of zinc was obtained in product 4, this may be due to the added mango juice (20%) contains low amount of zinc. The loss of iron during juice preparation due to leaching can contribute to the reduced levels iron analysis showed [11]. Zinc contents of product 1 & 6 and Product 2 & 5 were not significantly different (table 5.2). This could be due to the amount of zinc in OFSP and the added mango juice.

The iron content of the samples varied from 0.093±0.067 to 0.296±0.03 mg/l. There was no significant difference between iron content of Product 7 & 5, 1 & 6, and 2 & 3. The lowest value of iron was contained in product 4 but product 7 had highest in iron content. The highest value of iron was contained in product 5 and 7; this could be attributed to both the ginger (0.6 mg) and OFSP (0.5 mg) that have better iron content [50]. The lowest value of iron was recorded in product 4; due to the relatively low iron in mango juice and loss of iron during preparation due to leaching [11].

4.2.2. Phytate and Bioavailability

The analytical results of phytate and bioavailability of minerals (iron and zinc) is shown in Table 4.3. Results of phytate and bioavailability varied at $p<0.05$ depending on blending ratio and formulation. The phytate content of the products was between zero & 0.0035±0.0014 mg/l. The highest value of phytate was contained in product 2 but it was not detected in product 1, 3 and 4. Even though the juices were cooked for 2 hours at a temperature of 60-70°C and pasteurized at 90°C for 10 minutes, phytate was detected in ginger flavored products, This can be characterized by the ginger that contains high amount of phytate than OFSP and mango juice [49, 36]. The highest value of phytate in product 2 could be due to the high percent of OFSP whereas the lowest value in product 6 could be due to lower percent of OFSP. Phytate is good metal chelator and prevents absorption minerals by the intestine, which has negative nutritional impact on metals necessary for good health especially iron and calcium [21, 24, 40].

As stated in table 4.3, the molar ratio of phytate to zinc varied from 0 to 0.0073±0.00015. The molar ratio of phytate to zinc was nil for product 1, 3 and 4 but the highest molar ratio of phytate to zinc was contained in product 5. According to Norhaizan [35] the suggested critical molar ratio of phytate to zinc must be greater than 15. But molar ratio of phytate to zinc for product 2, 5 & 6 is much smaller than the critical value. Therefore the amount of phytate present in these products is none significant to hinder bioavailability of zinc in the products. Similarly, molar ratio of phytate to iron varied from zero to 0.0042±0.00012. The highest molar ratio of phytate to iron was contained in product 5, since product 5 contains lower phytate than product 2 & 6. As the phytate content was not detected in product 1, 3, 4 and 7, the respective phytate to iron molar ratio became nil. According to Norhaizan [35] the suggested critical value for phytate to iron must be greater than 1 (phytate/iron >1). However, calculated phytate to iron molar ratio of product 2, 5 & 6 are too small compared to the critical value. Therefore, the available phytate is not significant to hinder the absorption of iron too.

4.3. Sensory Evaluation

As indicated in the table 4.4, results of sensory evaluation of the juice products varied at $p<0.05$. The results of appearance varied from 2.86±0.58 to 4.58±0.56. Product 7 scored highest in appearance while product 1 scored lowest. There was no significant difference between product 2 & 3, and 4 & 5. The lowest value in appearance of product 1 could be due to high TSS, thick and viscous character observed (Table 4.1). Thick and clumsy nature of the product decreased acceptability of the appearance [17]. Next to product 7, the highest value of appearance (3.79 ±0.63) was recorded for product 6, this may be due to the mango juice and ginger blended enhanced the appearance of the product. The study revealed sensory acceptance of appearance of the juice increased with increasing of mango juice and decreasing of OFSP.

The aroma score of juice products ranged from 3.62±0.67 to 4.46±0.62. Product 6 scored highest aroma value but product 1 scored the lowest. Aroma score of product 3 & 4, and 6 & 7 was not significantly different. The aroma scores indicated are within the acceptable range. Ginger flavored juice products had better aroma. This is may be due to ginger contains better aromatic compounds than OFSP & mango [16, 17, 29, 41]. Color score varied from 2.79±0.56 to 4.68±0.47. Product 6 scored highest value of color whereas product 1 scored lowest. The highest score for color is related to high percent of mango juice combined with ginger that enhanced the color of the juice [17, 29, 53]. Browning reaction that took place during cooking may also contribute to the orange color of OFSP to slight brown [38]. Comparatively mango juice flavored products had better color sensory score.

Taste values of the products were between 3.80±0.71 & 4.35±0.66. The highest taste result was scored for Product 7 but the lowest value was recorded for product 3. Product 1 & 6, 2 & 5, and 3 & 4 were not significantly different. The highest acceptable taste results (4.17±0.71) was recorded for product 6 (79% OFSP, 20% mango juice and 1% ginger) and product 7 (commercial mango juice). This is due to the combination of the ingredients added generated suitable taste for the juice product [6, 14, 18]. Juice products may have sweet taste contributed from sugar, sour taste due to the presence of organic acids like citric, tartaric, acids and salty taste developed during interactions of minerals and organic acids [32]. The mouth feels score of the juices ranged from 3.72±0.59 to 4.5±20.65. The highest values were scored for Product 7 but the lowest value for product 1. There was no significant difference between product 2 & 3, 3 & 4, and 5 & 6. Mouth feel is the feeling in the mouth when the product is eaten and it is usually supported by measuring the product's viscosity [6, 32]. The low mouths feel score recorded for product 1, could be due to the high percentage of OFSP which resulted in high viscosity. The pseudoplastic nature of OFSP feels sticky in the mouth after drinking [37]. The High mouth feel score product 5 & 6 might be due to mango juice and ginger added resulted in smooth texture, easy to drink and low viscosity [32]. Product 7 had also highest mouth feel score due to the product has low viscosity, smooth nature and ease of drinkability.

Overall acceptability of the products was between 3.45±0.56 and 4.55±0.47. Product 7 scored the highest value of overall acceptability whereas product 1 scored the lowest value. There was no significant difference existed among product 3, 4 and 5. Overall acceptability summarizes the acceptability of all sensory attributes of the product. Next to product 7, the highest overall acceptability score (4.28±0.65) was recorded for product 6, which can be associated with the combined effect of OFSP, Mango juice and ginger that can enhance the juice's overall sensory acceptability [18].

5. Conclusions

Based on the findings of this experimental work, physico-chemical, nutritional and sensory properties of the juice products developed altered based on the formulation used. OFSP-based juice products containing ginger seemed to have improved acidity while products with higher OFSP had elevated soluble solids and viscosity. Better β-carotene content was attained in products which contain higher OFSP. Mango juice flavored OFSP juices had enhanced vitamin-C and the higher the percent of mango juice added the better vitamin-C can be contained. Improved concentration of total mineral, zinc and iron obtained in ginger flavored OFSP products. Phytate was detected in the ginger containing products. However, the amount of phytate present in these products is none significant to hinder the bioavailability of zinc and iron. Even though, the overall acceptability test indicated all juice products scored acceptable evaluation, products flavored with combined OFSP, Mango juice and ginger were observed to have enhanced overall sensory acceptability. Generally during development of OFSP juices combinations of ingredients should be considered to improve overall quality and stability of the products.

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