Development of Orange Fleshed Sweet Potato (OFSP) Based Juice Drink to Help Reduce On Vitamin A Deficiency

Lubowa Muhammad[1], Yerbie Aminah[2], Kisambira Abbas[3]

[1]Islamic University in Uganda, Department of Food Science and Nutrition, Mbale, Uganda

Abstract: ***VAD is a serious public health problem in many developing countries. The aim of this research was to develop an acceptable OFSP based drink to help in the prevention of VAD. The drink was formulated from OFSP and Pineapples. The acceptability of the formulations developed was evaluation followed by determining the physico-chemical characteristics of the most accepted juice drink which involved titratable acidity, total soluble solids, pH and vitamin A content as β-carotene. Results indicated that the formulation (F4) was the most accepted followed by F3, F1, F2 and F5. Physic-chemically, the juice drink from the most acceptable formulation has a pH of 4.90, TSS 8.0%, TA 1.4 g/ml and vitamin A content of 9344.08 µg/100 RAE. The developed OFSP based drink has the potential to help reduce on VAD in most developing countries.***

Keywords: Orange-fleshed sweet potatoes, *Ipomoea batatas*, VAD, Juice

1. Introduction

Sweet potatoes are native to the tropical Americas and were first cultivated at least 5,000 years ago [1]. They spread very early throughout the region including the Caribbean now known as southeastern United States [2]. They were brought to Europe by Spanish and Portuguese explorers and sweet potato cultivation quickly spread throughout much of the Old World up to Africa [3]. There are various varieties of sweet potatoes like the purple sweet potato known as '*okinawan*', the *o'henry* sweet potato which is white with a cream colored flesh [4]. The most important variety of interest in this study is the orange fleshed sweet potato (OFSP) which is known to be very rich in vitamin A [4]. Scientifically the orange fleshed sweet potato also known as *ipomoea batatas* is a member of the *convolvulaceae* family of flowering plants [3], [5]. In Uganda, about 19 OFSP clones a believed to have been introduced from CIP Lima and Peru in February 2001 [6], but two landrace cultivars of OFSP, designated as 'SPK004' ('*Kakamega*') and 'Ejumula' are the ones widely grown as a result of farmer–to-farmer exchange or purchase of planting materials and promotions by nongovernment organizations, schools, farmer groups and government departments.

Most cultivars have spreading vines and vigorous growth with dense foliage that suppresses aggressive weeds [7]. The flower color in most cultivars is the same pale purple limb with purple throat. Flowering is moderate in 'SPK004' and sparse in 'Ejumula' whereas capsule formation and seed set are sparse in both cultivars enabling crosses to generate breeding populations under NACRRI conditions without special treatment. According to [6], both cultivars have high root dry matter content (greater than 30%) and a dry texture with a sweet taste when cooked. Flesh color ranges from light orange (orange with yellow patches) in 'SPK004' to deep orange in 'Ejumula' with intensity varying according to age of roots, location, agro climatic factors such as soil type and season (wet/dry).

Vitamin A deficiency is a serious public health problem in many developing countries including most of the countries of eastern, central and southern Africa [8]. It mainly affects the poor, young children (6 months to six years of age), and pregnant and lactating women. The clinical form of vitamin A deficiency, xerophthalmia results when the eye is adversely affected and is expressed as night blindness or at its most severe as total irreversible blindness [9]. Sub-clinical vitamin A deficiency affects many more people an estimated 227.6 million in 2005 and results in increased sickness and death rates due to diseases such as diarrhea and measles among those affected. It also contributes significantly even at subclinical levels to morbidity and mortality from common childhood infections in children [8]. An estimated 2.8 to 3 million pre-school-age children are clinically affected and 251 million more are severely or moderately sub clinically deficient. At least 254 million children of pre-school age are thus "at risk" in terms of their health and survival [8]. The prevalence among pregnant and/or lactating women is ≤1%, which is also a public health problem [10].

The adverse effects of VAD are heightened in developing countries like where abject poverty often prevents people from eating and growing more nutritious food. In such areas the development and dissemination of highly nutritional fortified crop varieties has lagged behind than that of more developed. Traditionally white or yellow sweet potato varieties are grown and eaten in Africa but these provide little or no vitamin A. OFSP was conventionally been bred not just to provide more vitamin A but also to be high yielding and drought tolerant [11]. OFSP has a high content of carbohydrate besides other simple sugars and β-carotene. They also contain protein (1.6g), dietary fiber (3.0g), vitamin C (3%) and vitamin B6 (0.2%). They majorly consumed as the main meal and also used for animal feeds [12].

Pineapples on the other hand mainly contain water, carbohydrates, sugars, vitamins A and C. It contains low amounts of protein, fat, ash and fiber [13]. Pineapples contain antioxidants namely flavonoids, vitamin A and C. It also has the enzyme complex protease (bromelain). Bromelain contains peroxidase, acid phosphate, several protease inhibitors and organically bound calcium [13]. Pineapple is a tropical fruit which is consumed fresh or in a processed form. It is largely consumed around the world as canned pineapple slices, chunk and dice, pineapple juice, fruit salads, sugar syrup, alcohol, citric acid, pineapple chips and pineapple puree [14]. About 60% of fresh pineapple is edible [15].

There is need to add value and develop products from OFSP to improve on the keeping quality and utilization of the tuber. Therefore this research was aimed at developing an orange fleshed sweet potato based juice drink from the readily available tubers which are rich in vitamin A to help curb on the preventable cases of blindness as it is more convenient and will have a longer shelf life than the fresh orange fleshed sweet potatoes.

2. Materials and Methods

2.1 Raw Materials and Equipment Procurement

The OFSPs were purchased from Nkoma road side local market in Mbale district (Uganda), particularly from a farmer known to produce OFSP. The pineapples were also purchased from the same market. Other ingredients and equipment needed during processing like sugar (1kg), plastic bottles, knives, blender, spoons, grater, sieve and disposable cups were purchased from BAM shopping center in Mbale town.

2.2 Preparation of the raw materials

The raw materials were prepared and juices extracted from them following the process illustrated in figure 1.

2.2.1 Blending the juices

Different proportions of the two juices were mixed to make five formulations, at this stage equal weight of sugar was added. Two (2) tablespoons of sugar were added to 500mls of the blended formulations.

Table 1: Formulation of the juice drinks developed from OFSP and pineapple

	Formulations				
Juice	F_1	F_2	F_3	F_4	F_5
OFSP%	50	60	70	80	90
Pineapple %	50	40	30	20	10

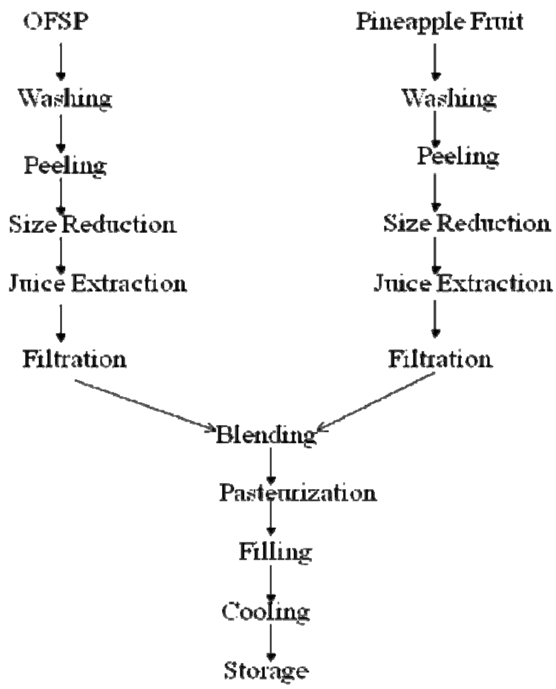

Figure 1: Flow chart for OFSP based juice drink production

2.2.2. Pasteurization

Pasteurization of the developed formulated juices was done at 72 ° C for 15 minutes. This was to destroy the pathogenic microorganisms and the enzymes present in the juice that would cause spoilage. This would help to extend the shelf life of the juice.

2.2.3. Filling and cooling

The blended juices were hot filled in 500mls sterilized plastic bottles in order to expel off the air in the juice and then the product was cooled in a refrigerator.

Figure 2: OFSP based juice drink formulations

2.3. Sensory Evaluation

Sensory evaluation of the formulated product was done at Islamic University in Uganda from the food science laboratory. A panel of thirty untrained panelists was selected from volunteers among the students of Islamic University in Uganda (Mbale campus) to assess the overall acceptability, appearance, aroma, taste and mouth feel of the formulated products. Before the study, all panelists were briefed about the procedure and each had to verbally consent to participation. All the participants were nonsmokers, fluent in English, self-reported to have normal taste and smell sensitivity. Panelists were requested to refrain from eating or drinking for at least 1 hour before the scheduled time for tasting. For sample evaluation, 50mls of the product samples from each formulation was placed into plastic disposable cups coded with 3 digit random letters. Samples from each formulation were served to each panelist. Samples were presented to panelists in random order. Also in addition to the Samples, panelists were provided with water and paper ballots. Panelists were instructed to consume the whole sample and rinse their mouths with water between samples to minimize any residual effect and they were also instructed to fill the paper ballots. A 9-point hedonic scale ranging from extremely dislike to extremely like was used to evaluate the acceptance of the five product formulations attributes.

Figure 3: Sensory evaluation panelist

2.4. Physico-Chemical Analysis

The best ranked sample in terms of overall acceptability was subjected to chemical analysis to determine the pH, titratable acidity, total soluble solids and Vitamin A content as β-carotene.

2.4.1 pH determination

The pH meter was used to determine the pH of the juice. The juice (30mls) was put into a clean small beaker and then the pH meter electrode was inserted in the juice and the pH value of the juice was read and recorded. This was done in triplicates and the average value was considered for accuracy.

2.4.2 Total soluble solids determination (Refractometer method)

Drops of the juice (1-2) were put on a clean eye piece type refractometer glass and the brix in percentage was read and recorded.

2.4.3. Titratable acidity determination

To 10mls of the juice 3-4 drops of phenolphthalein was added followed by titration against 0.1M sodium hydroxide solution. Titratable acidity was computed using the formula:

$$\%TTA = \frac{titre(\text{mlsofNaOHxFxVol.ofextractionwater*100})}{Vol.ofsampleforTitrationxS}$$

Where S=grams of sample taken
F=factor of principle for malic acid and citric acid is 0.067 and 0.064 respectively.

2.4.4. Vitamin A determination

Vitamin A content was determined according to the method described by Rodriguez-Amaya and Kimura [16]. Vitamin A was determined as beta carotene and the method used involved; carotene extraction, partitioning with petroleum ether and use of a spectrophotometer.

(a) Sample preparation

The OFSP tuber was peeled using a knife and later cut into quarters then the two diagonal pieces were used as representative samples. The pieces were crushed/grated using an electric blender. The crushed OFSP was weighed (1gm) and then transferred into a mortar and ground using a pestle during extraction using acetone. The juice sample was mixed thoroughly/homogenized to ensure uniformity before extraction using acetone.

(b) Carotene Extraction

Carotene was extracted from 4mls of the sample using 50mls of cold acetone for 1 minute. The sample was first homogenized then mixed with 50mls of cold acetone for a few minutes and then filtered. For the OFSP tuber 1gm of the crushed sample was obtained and finely crushed using a pestle and mortar while adding in acetone, after the extraction the sample was put in a 50ml volumetric flask and filled to the 50ml mark with acetone. This was done in duplicates to minimize errors.

(c) Partition to Petroleum Ether

Petroleum ether (PE) (30ml) was mixed with the sample in a 500 ml separatory funnel and 50ml of the acetone extract was added. Slowly distilled water (250ml) was added and let to flow along the walls of the funnel. To avoid formation of an emulsion shaking was avoided. The two Phases were separated and the lower aqueous phase was discarded. Residual acetone was removed by washing with 250ml of distilled water 3-4 times in the separatory funnel. In the last washing effort was made to discard off the lower phase as completely as possible without discarding any of the upper phases. Then PE phase was collected in a 50 ml volumetric flask. The solution was made to pass through a small funnel containing anhydrous sodium sulfate (15 g) to remove residual water by putting a glass wool plug to hold the sodium sulfate. The separatory funnel was washed with PE and it was collected in a 50ml volumetric flask. The samples were then kept in a dark place to prevent oxidation of the β-carotene by light.

Figure 4: Partitioning stage during β-carotene determination

(d) Spectrophotometric reading and calculation

The absorbencies were read at 450nm. It is also necessary to either dilute or concentrate the carotene solution. The total carotene content was calculated using the formula below:

Total carotene content (μg/g)

$$= \frac{A * volume(ml) * 10^4}{A^{1\%}1cm * sampleweight(g)}$$

Where A=absorbance
Volume =total volume of extract.
$A^{1\%}_{1cm}$=absorption coefficient of β-carotene in PE (2592)

2.5. Data Analysis

All experimental analyses in this study were done in triplicates. All data was analyzed using SPSS version 16. Analysis of Variance (ANOVA) was performed to calculate the significant differences in treat means at $p \leq 0.05$.

3. Results and Discussion

3.1 Sensory evaluation results

Results of the sensory evaluation of the different formulations of the developed juice drinks are indicated in table 2. Generally there was a significant difference in the overall acceptability of the different formulations.

3.1.1 Flavor

Sensation caused by properties of any substance taken into the mouth which stimulates one or both of the senses of taste and smell and/or also the general pain, tactical and temperature receptors in the mouth is known as flavor [17]. Results in table 2 indicate that there was no significant difference in flavor between formulations of F1 and F2 *($p \leq 0.05$)*. But there was a significant difference between formulations F3 and F4, F3 and F5, F4 and F5. The flavor for formulation F1 was the most preferred followed by F4, F3, F2 and then least for F5. The high preference for F1 may be attributed to the considerable amount of pineapple (50:50) ratio of OFSP to pineapple juice. The pineapple may have contributed to the sweet flavor. It has flavor compounds majorly esters like; ethyl-2-methylbutyrate, methyl-2-methylbutyrate, 3-(methylthio) propanoic acid, ethyl ester, ethyl hexanoate and decanal [18], unlike the OFSP juice which had a mild flavor. Therefore blending the pineapple helped to improve on the flavor of the juice.

3.1.2 Appearance

There was no significant difference in the color of formulations F1, F2, F3, F4 and F5 *($P \leq 0.05$)* (Table 2). The appearance of F2 and F5 were fairly liked unlike formulations F1 and F3 which were least liked. The Appearance of F4 was most preferred to that of the rest of the formulations and it might have stemmed from the fact that the formulation had more OFSP juice (80%) which provided a bright orange color. The bright orange color of OFSP is attributed to the β-carotene in the OFSP [19]. Formulation F4 and F5 had a good appearance since they had a substantial amount of OFSP. The typical color of the OFSP is primarily due to the carotenoid pigments present [19].

3.1.3 Taste

Taste as a sensory attribute is defined as a sense that distinguishes the sweet, sour, salty, and bitter qualities of dissolved substances in contact with the taste buds on the tongue [20]. Results in table 2 indicate that there was no significant difference between formulations F1, F3 and F4 with the rest of the formulations *($P \leq 0.05$)* but there was a significant difference in the taste of formulations F2 and F5 *($P \leq 0.05$)*. The taste preference for formulation F4 was the highest followed by F3, F2, F1 and formulation F5 had the least preference. F4 was most preferred may be because there was a better balance of the taste in the juice blend of 80:20 OFSP juice to pineapple. In some cases the panelist observed that OFSP had a blunt taste like in formulation F5 which comprised 90% OFSP. This could be because of the high pH implying a low amount of acid in the formulation. Some panelists commented on F1 which had a ratio of 50:50 (OFSP to pineapple) as being sweet. This could be attributed to the inherent sugars present in the pineapple like sucrose and fructose [18]. The taste of the formulations is basically based on the OFSP, pineapple and sugar content of the drink. Combination of all the ingredients helps to give an acceptable taste.

Table 2: Mean scores of sensory evaluation of the formulated OFSP based juice drink

Formulation	Flavor	Appearance	Taste	Body	Overall acceptability
F1	8.23±0.89[a]	7.20±1.03[a]	6.87±1.56[a]	7.10±1.56[c]	7.33±0.71[bc]
F2	7.23±0.97[a]	7.57±0.77[ab]	6.93±0.94[b]	7.00±1.46[d]	7.13±0.97[a]
F3	7.30±1.37[c]	7.27±0.94[a]	7.13±1.36[a]	7.23±0.97[b]	7.30±0.92[d]
F4	7.63±1.03[b]	8.30±0.54[a]	8.30±0.84[a]	8.30±0.70[a]	8.70±0.54[ab]
F5	7.10±1.61[d]	7.37±1.61[a]	6.37±1.63[c]	6.87±1.61[a]	6.00±1.93[e]

Values ± SD with the same super script in the same column are not significantly different while those with the different super script letters are significantly different at p≤0.05.

3.1.4 Body/mouth feel

The term body describes the physical properties like; heaviness, thinness, oiliness, graininess, or wateriness of the juice as it settles on your tongue [17]. Discerning body involves identifying its tactile impression, consistency and weight as perceived in the mouth at the back of the tongue when you swoosh the juice around in your mouth and also after swallowing or after spitting the juice out [17]. Results in this study (table 2) showed that there was a significant difference between formulations F1and F2, F2 andF3, and F1 and F3 *(P≤0.05)*. But there is no significant difference seen between formulations F4 and F5 with the rest of the formulations *(P≤0.05)*. There was a high preference for the body of formulation F4 followed by F3, F1.F2 and F5 was liked least. It was also observed in the study that the higher the OFSP extract content, the lighter the formulation's body. This might be attributed to the fact that the OFSP juice had a light body and also the TSS contributes to the body of the juice. The preparation method of the juice drink could also be a factor that affected the body due to the amount of water added during processing. The amount of water added during preparation might have contributed to the light body of the formulations [19].

3.1.5 Overall acceptability

There was a significant difference in the overall acceptability between formulations F3 and F5 (p≤0.05) but there was no significant difference between formulations F1, F2 and F4 with the rest of the formulations (P≤0.05). The preference for formulation F4 was highest followed by F3, F1, and F2 and least for F5 as shown in table 2. The high acceptability scores (8.70±0.535) of F4 could be attributed to the substantial proportions of the pineapple juice as it has better sensory attributes particularly taste, body and flavor. The high proportion of OFSP contributed to the color then the other attributes for which the OFSP juice was inferior were improved on by the blending in the pineapple thus contributing to the ultimate acceptability of the formulation (F4).

3.2 The Results of the Physico-Chemical Characteristics of the Most Acceptable Formulation

3.2.1 pH

Results in this study indicated that the drink had a pH of 4.9 (Table 3).

Table 3: Physico-chemical characteristics of the most accepted formulation (F4)

Constituent	Mean value*
pH	4.9±0.10
Total soluble solids (%)	8.0±0.00
Titratable acidity (g/ml)	1.4±0.06

*All values are means of triplicate determination ± SD.

The mean pH of 4.9±0.10 indicated that the juice drink was slightly acidic compared to the pH of other fruit juices like pineapple juice which has a pH range of 3.0-3.1, and watermelon 5.2-5.8 [17]. The high pH might have an implication on the keeping quality of the juice because the high pH would proliferate the growth of spoilage microorganisms. This may warrant addition of acidulates like citric acid to lower the pH to the desired level to may be 3.5-4.0 [21].

Lowering the pH also has an effect on the flavor of the juice and it also improves on the keeping quality of the juice [22]. Blending the pineapple juice with the OFSP which inherently has a high pH could have caused the formulated product to have a relatively high pH. According David *et al.* [21], the pH of orange fleshed sweet potatoes is between 5.9-6.0 and that of pineapples is 3.0-3.1[17]. This can imply that the pineapple might be responsible for the slightly low pH compared to that of the OFSP juice.

3.2.2 Total soluble solids

TSS is widely used to determine the concentration of sugar in products. It is expressed in degrees brix [17]. According to [17], the total soluble solid of the OFSP juice is between 12.57-13.78 ◦ brix and that of pineapple juice is between 11-13◦ brix. The formulated juice has a TSS of 8.0◦ brix and this is slightly lower than the TSS reported from other ready to drink juices. This juice may be good for consumers who are interested in taking less sweet juices and it may not be good for those with a sweet tooth. The TSS of the fruit juice depends on a number of factors like; maturity stage of the fruits, Cultivar, crop size, cultural practices and growing season. They also influence the amount of sugar added to the final product.

3.2.3 Titratable acidity

The titratable acidity measures the organic acid content of the juice drink (McCarthy, 2007). In this study, a TA value of 1.4g/ml was recorded (Table 3). This TA falls in the range of the TA for the pineapple (0.7-1.6g/ml) and that of the OFSP juice (0.36-0.6g/ml) [23]. This is because most of the acid (citric acid) is from the pineapple and not the OFSP juice since it is has a low acid content.

3.2.4. β-carotene and vitamin A content of the OFSP tuber and the most acceptable formulation

Results of β-carotene and vitamin A of the most accepted formulation and the OFSP tuber are indicated in the Table 3

Table 4: Mean values of the Beta-carotene and Vitamin A of the most accepted formulation and the OFSP tuber

	Beta-carotene (μg/100g)	*Vitamin-A (μg/100gRAE)*
Sample (F4)	3713.35±682.01[b]	309.45±56.83[c]
OFSP Tuber*	112120.49±4461.23[a]	9344.08±371.77[a]

Values with the same super scripts in the same column are not significantly different while those with the different super scripts are significantly different at p≤0.05.*values of OFSP tuber are expressed on dry matter basis.

The results in Table 4 indicate that there was a significant difference in the β-carotene content of formulation F4 and the OFSP tuber (p≤0.05). Similarly also there was a significant difference in their vitamin A content on expression as the β-carotene was expressed as vitamin A.

The β-carotene content also expressed as vitamin A was higher in the OFSP tuber compared to the formulation (F4) as shown in the (table 4). This could have been because of dilution with water during processing thus the formulation had a lower β-carotene content. This might have also been caused by the exposure of the OFSP during processing to make the formulation to oxygen during different unit operations like, peeling, cutting, grating and blending because β-carotene is sensitive to heat and oxygen. On fresh weight basis light orange varieties contain at least 250 RAE/100 gm (30 μg/g), medium-intensity varieties at least 458 RAE/100 gm (55 μg/g) and dark-orange -varieties at least 833 RAE/100 gm (100 μg/g) of β-carotene [24]. The recommended dietary allowance (RDA) for vitamin A for infants (0-12months) is between 400-600μg/day, children 4-6yrs is 500μg/day, children 7-10yrs 500-900μg,males (13-≥70yrs) 600-3000μg/day, females (≤19 up to above 70 yrs) 800-3000μg/day and pregnant women (19-above 50 yrs) 750-4000μg/day, lactating women (19-above 50 yrs) 1300-4000μg/day [25]. The formulated juice drink with β-carotene content (3713.35μg/100g) and vitamin A content (309.45 RAE) would meet the vitamin A RDA for most of the age groups thus reducing on VAD.

4. Conclusion

The production and processing of locally available agricultural produce plays a very crucial role in income generation, nutrition status, employment opportunity and improvement of nutrition and socio-economic status of the rural poor who are the majority of the population in Uganda. The OFSP based juice drink is one of the several value added products that can be produced from the locally grown food crops and fruits.

The development of an acceptable OFSP based juice drink was possible and successfully done. It was possible to formulate an acceptable OFSP based juice drink made up of locally available pineapples and OFSP (OFSP as the major component). Physico-chemically the most acceptable juice drink formulation (F4) had a pH (4.90) which may compromise its keeping quality. The juice drink also had substantial quantities of vitamin A (309.45±56.83) thus the juice drink can be used to combat VAD

5. Future Scope

Further research on the shelf life and microbiological stability of the juice drink is recommended. Due to the high pH (4.90) of the juice drink, it is recommended that acidulants should be added to lower the pH in order to improve on the juice drink's stability during storage.

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Author Profile

Lubowa Muhammad is a lecturer at the Department of Food Science and Nutrition of the Islamic University in Uganda. He has previously studied at Makerere University (Uganda), from where he has obtained extensive research experience and knowledge of Food Science and Technology. He also guides and advises bachelors’ students in research projects.