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Production, Utilization and Nutritional benefits of Orange Fleshed Sweetpotato (OFSP) Puree Bread: A Review

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Abstract

Bread though an exotic food product in sub-Saharan Africa, has been an important cereal product consumed by most individuals among the vast Sub-Saharan African population. Bread formulations in both the local and industrial production have evolved. The latest and emerging technology in bread formulation involve the incorporation of orange-fleshed sweetpotato (OFSP) puree. OFSP puree-based bread is commercially available across sub-Saharan Africa (SSA) and is being promoted due to the potential nutritional benefits that it possesses. Together with OFSP flour based bread, OFSP puree based bread serves as a good food vehicle for β-carotene; this serves to alleviate vitamin A deficiency (VAD) especially among the vulnerable population in SSA. The production of OFSP puree based bread has so far been relying on fresh OFSP puree or cold-chain stored OFSP puree. However, this has presented economic challenges and problems to the sustainability and expansion in OFSP puree bread production. Cold chain stored OFSP puree is capital intensive and has inconsistent supply. With the development of shelf-storable preservative treated OFSP puree, most of these challenges will be overcome without undoing the currently harnessed benefits. The use of OFSP puree in bread baking can then be expanded easily at minimal production costs and maximum retention of nutritional quality. Therefore, the use of the shelf-storable OFSP puree in bread baking needs to be evaluated further to present a substantiated case for its use. The current review has been developed with focus on the scientific advances in the production of OFSP puree based bread from both historical and a forecast perspective. The scientific progress and breakthroughs in the use of OFSP puree in bread are critically reviewed.

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Introduction

Bread is a baked product of flour or meal of cereals, especially wheat which includes ordinary, unleavened and leavened types.[1] Bread production dates back to over 12,000 years ago (around 10000 BC) with the Egyptians as the pioneers, and was probably a deliberate experimentation with water and grain flour.[2] Bread baking is a widely done practice globally with a quite diverse recipe. Baking of leavened bread must have been developed accidentally through the exposure of crushed grain to yeast cultures. It is estimated that around 1,000 BC, the Egyptians isolated yeast and used it in bread baking, helping them to produce bread to the tune of thirty varieties.[3] The spontaneous fermentation of bread was replaced with controlled process of fermentation in late 19th Century yielding increased fermentation speed, better bread quality and consistency.[4]

Bread production has spread all over the world with different countries having different kinds of domesticated bread production methods.[5] Bread production has evolved over the ages in terms of ingredients used. Latest developments in bread production has led to the advancements in the bread industry that have enabled the use of various composite flours including purees to produce bread with improved sensory acceptability and physico-chemical quality.[6,7] Latest advances in bread baking have enabled the incorpotation of OFSP puree into bread to improve the vitamin A content of these breads[8]. This had the aim of extending the value-chain of OFSP roots and increasing its market space, thus improving its uptake and utilization. Commercial production of OFSP puree bread is in practice across many countries in sub-Saharan Africa, including Kenya. However, the utilization of this β-carotene rich bread is still low as a result of limited production. Technological and marketing challenges have also occasioned the low utilization of this puree in bread baking. This review focuses on the utilization of beta-carotene rich OFSP-puree bread, its nutritional benefits as well as the prospects and opportunities to improve its uptake and utilization.

Orange-Fleshed Sweetpotatoes (OFSP)

OFSP variety of sweetpotato was developed through conventional breeding in 1995.[9] The utilization of OFSP roots in the alleviation of Vitamin A deficiency (VAD) in countries like Guatemala was recorded in the early as in the mid-1990s.[10] Sweetpotatoes have been promoted for their calorie-rich value, but the OFSP has been greatly recommended for the reduction of VAD in developing countries such as Asian countries.[11] The chemical composition as well as the nutritional composition of the OFSP roots is largely influenced by the genotype and growing conditions,[12,13] thus the variety grown must be suited to the intended purpose.

Originally in SSA, great reliance was on white-fleshed or yellow-fleshed that had established markets; however, the beta-carotene content of both the white and yellow-fleshed sweetpotato roots is low as compared to the OFSP.[14] Over forty cultivars of OFSP roots have been introduced in Africa.[15] Some of the sweet potato varieties that have been tried and grown in Kenya include KENSPOT-3, KENSPOT-4, KENSPOT-5, Kabode (NASPOT 10-O), Vitaa, Simama, Pumpkin, Japanese, Kakamega 4, Local check, NASPOT 9-0, Vindolotamu and Vitamu A.[16] The varieties that have been exploited in puree processing by the sole processor in Homabay County of Kenya, are Vitaa and Kabode.[17] The β-carotene content of OFSP varieties vary depending on the intensity of the orange colour on the flesh, with lighter orange flesh coloured varieties having lower β-carotene levels.[18,19]

The nutritional composition of orange fleshed sweetpotato is as summarized in Table 1. OFSP roots can be exploited for their calorie-rich property to alleviate protein-energy malnutrition (PEM), but has majorly been recommended for fighting VAD.[20] OFSP roots are rich in provitamin A carotenoids than other sweetpotato varieties including cream and white fleshed varieties. β-carotene in its form of 13-*cis*, *all trans* and 9-cis comprise 10-93% of total carotenoid in OFSP roots 9. Studies have reported a beta-carotene content ranging between 0.03 and 13.63 mg/100g fresh weight for different varieties of OFSP roots.[13,21–23] A study by Islam[24] that compared the beta-carotene content of different sweetpotato varieties reported a higher beta-carotene content of 19.31-61.39µg/g in OFSP roots as compared to those of the white, yellow and cream fleshed sweetpoatoes which were 1.02, 3.28-5.64 and 3.7839µg/g respectively. Even upon cooking, the OFSP roots still provide high levels of beta-carotene.[22] Mitra

19 reported the β-carotene retention of exotic and indigenous varieties of sweetpotatoes grown in India as 76.56-87.76%; providing beta-carotene content of 4060-9740µg/100g fresh weight. However, it has been reported that with increasing beta-carotene content in OFSP the dry matter content decreases.[25] In another study, it was established that the acceptability of OFSP roots is not only positively influenced by appealing colour and taste, but also a higher dry matter content.[26] Additionally, Bengtsson *et. al.*[27] reported an increase of up to 46% in the in vitro bioaccessibility of β-carotene for OFSP roots prepared with fat as compared to just 41% for OFSP roots without fat. This gives credence to the use of OFSP roots with lower dry matter but a higher beta-carotene content as a functional ingredient in bread baking.

Utilization of Orange Fleshed Sweetpotato

OFSP tubers have been utilized as food in their fresh form after cooking, as flour and in the grated and mashed (commonly known as puree) forms.[31–33] OFSP flour has been used locally at domestic level and in industrial production of bakery products. Some of the bakery products in which OFSP flour is incorporated as an ingredient are cakes, bread, muffins and buns.[34] Mashed OFSP has also been used for flour substitution in Golden bread.[35] OFSP is being promoted as a nutrition intervention to tackle VAD and food insecurity in many countries.[36] In industrial production, OFSP has beeen used to produce products such as chips, crisps, flour, puree, juice, bread and other bakery products.[37,38] In Asian countries, sweetpotato pickles and cubes are produced commercially and are known for their β-carotene rich property.[39] Some of the OFSP roots such as Beta 1 and Beta 2, main varieties grown in Indonesia, are high in moisture thus are not consumed directly as roots but in derivative products.[40] In such cases, OFSP roots are processed and serve as functional ingredients. Production and use of OFSP puree as functional ingredients in food processing has been done for over three decades in the United States (US).[33] OFSP roots have also been exploited in stockfeeds as root meal especially in the raising of pigs and in other food processing such as starch extraction in Asian countries.[41] The use of OFSP roots for starch extraction is limited as the dry matter content of these roots are quite low.[42]

OFSP puree is incorporated into bread as a functional ingredient to increase the provitamin A composition of this bread. The substitution of wheat flour with OFSP puree in bread baking has been done at varied levels in different studies.[43,44] The use of OFSP to substitute wheat flour in bread is aimed at increasing the uptake and utilization of OFSP roots. The commercialization of the OFSP puree bread creates a market for the OFSP roots; this trickles down to improve the rural economies of households involved in the production of OFSP roots.

Table 1: Nutritional Composition of sweetpotato roots (per 100g fresh weight)

Nutrient	Orange-Fleshed	White-Fleshed	Cream-fleshed	Yellow-fleshed
Dry matter (g)	25.09-38.56	27.79-31.64	35.46-40.3	31.26-41.12
Protein (g)	2.03-4.19	3.35-3.40	3.61-4.27	3.20-4.09
Fat (g)	1.74-2.22	0.67-8.88	1.29-1.45	0.54-1.81
Carbohydrates (g)	14.46-22.86	15.71-20.19	27.39-33.22	22.36-38.92
Ash (g)	3.03-4.70	3.53-3.70	1.52-3.00	2.56-3.61
Fibre (g)	2.19-3.00	2.35-2.51	2.00-2.11	1.81-2.56
Energy value (kCal)	90.24-153.63	100.39-156.18	137.06-161.49	115.68-176.96
Starch (g)	7.840-16.934	7.056-8.31	14.465-26.64	17.287-32.673
Reducing sugars (mg)	335-1086	122-270	114-325.8	38-1211
Total sugars (mg)	610-24268	700-2742	163-3370	2423-68443

Adapted from Sanoussi et al. [28], Omodamiro et al. 29and Nabubuya et al. [30]

Orange-Fleshed Sweetpotato Puree based Bread

OFSP roots have been exploited as functional ingredients in bread both as flours and puree.[29,45] Since 1990s, OFSP had been incorporated into bread production in Peru in grated form as little sun was available for sun-drying to produce flour.[46] Incorporation of OFSP in wheat products also has economic advantages as it was the case of cassava that helped reduce reliance on imported expensive wheat flour. The incorporation of either OFSP flour or OFSP puree in bread aims at improving the β-carotene content of bread.[47,48] The use of puree in the substitution of flour in bread baking presents an economic and nutritional advantage : the flour has a lower conversion rate of 4.5-5kg to produce a kilogram of flour compared to 1.3-1.6 kg of fresh root required to produce a kilogram of puree, and significant losses of β-carotene occur in the OFSP flour with storage beyond two months.[17,45,49] Omodamiro *et al.*[29] reported a flour yield as low as 21.5% from some roots of OFSP varieties. This necessitates alternative economical ways such as puree or paste for bakery products.[18,40,50]

Production of Orange Fleshed Puree for use in Bread Baking

The production of OFSP puree by the sole processor in Kenya follows the diagrammatic representation shown in Figure 1. The puree is usually stored frozen for later use, thus preserving most of its chemical and physical properties. The use of OFSP puree subjected to cold-chain storage presents a challenge in terms of additional costs as the storage demands electric power and additional equipment if the long term production is to be sustained, thus limiting the use of this puree by small scale bakeries that cannot afford the cold chain storage. Moreover, it has limited the quantity of puree that can be stored due to its resource intensive nature, thus resulting into inconsistent supply of the puree occasioned with massive spoilage of roots during glut and scarce supply of roots during shortage. This has occasioned limited production of this bread.

Current advances in research have enabled the production of preservative-treated shelf-storable OFSP puree that is stored away from light. The puree is preserved using potassium sorbate, sodium benzoate and citric acid accompanied with vacuum packaging enabling it to have a shelf-life of 4 months at 23°C.[17] Potassium sorbate, sodium benzoate and citric acid each singly has antimicrobial effect[51,52]. Synergism has been shown to increase the effectiveness of food preservatives.[53] A microbial challenge study by *Musyoka et al.*[8] found that the combination of potassium sorbate, sodium benzoate and citric acid result in a decline of 4 log cycles for *Escherichia coli* and *Staphylococcus aureus*. However, only the cold chain stored puree has been evaluated in bread baking. Moreover, OFSP puree

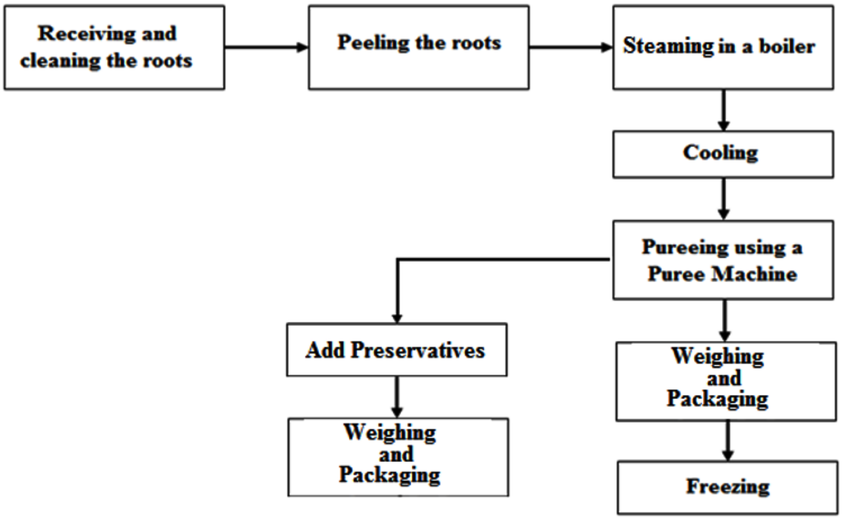

Fig. 1: Schematic representation of Puree Processing. Adapted from Tedesco and Stathers[54]

bread production in Kenya is only limited to the large-scale retailers such as supermarkets and very few small-scale retailers, thereby the availability of the OFSP bread is greatly limited. Marketability of bread made from shelf-storable OFSP puree also needs to be evaluated.

Production of Orange-Fleshed Sweetpotato Puree Bread

In developed countries such as European countries and the US, nutrition awareness has served to spur demand for OFSP thus increasing production of novel foods.[55] Utilization of OFSP as a fortifying agent in various foods in these countries has been a practice over time. OFSP puree has been used as an ingredient in commercial bread production in Kenya as a substitute for wheat flour with 40% being the optimal substitution.[56] In Ghana, the bread is on the roll out for industrial production under the trade name "vitabread".[31] In Rwanda, wheat flour substitution with OFSP puree in bread baking has been done in the proportions ranging from 20 to 45%.[56] Studies have documented that 30% OFSP puree incorporation into bread is the minimum level that possibly provide significant β-carotene levels[34] justifying the fortification of bread using OFSP puree. The use of OFSP puree as a substitute for flour has provided both economic and nutritional advantages.[31] The incorporation of OFSP puree in bread targeted the high end market who could not easily access the OFSP roots and benefit from its β-carotene rich property.[34]

The optimal product formulation is as shown in Table 2. Decline in the gluten impacts on the physical attributes of the bread especially the loaf volume of the bread. The vital gluten and improver are added to the formulation to undo the possible effects of the wheat flour substitution on the physical attributes of the bread such as the loaf volume, specific volume and the weight. Nwanekezi 57 reports that protein content equal to or less than 8% in the flour makes it virtually impossible to produce a quality bread. The baking of the OFSP puree bread follows the schematic representation showed in Figure 2.

Another great challenge that has greatly hindered the production of OFSP puree bread is that the production OFSP roots are seasonal. Such a challenge can be overcome by the utilization of preservative treated (shelf-storable) OFSP puree.[17] Bread made from shelf-storable puree is yet to be evaluated in terms of its physico-chemical, sensory attributes and shelf-stability. The adoption for use of this puree in bread production has advantages including high economic returns as there would be reduced spoilage of roots during glut, consistent supply of puree to bakeries and reduced bread production costs as the shelf storable OFSP puree has a shelf-life of up to four months at ambient storage (23°C).[15,17] The use of shelf-storable puree is also a better alternative for bakers who lack puree processing plants or cannot access fresh puree.[17]

Table 2: Optimal formulation for OFSP puree bread

Ingredients	Proportions
Wheat flour	60%
Puree	40%
Sugar (based composite puree-flour weight)	2%
Salt (based composite flour weight)	1%
Yeast (based composite flour weight)	1%
Shortening fat (based composite flour weight)	3%
Vital gluten (based composite flour weight)	0.50%
Dough Improvers (based composite flour weight)	0.50%
Water (based composite flour weight)	18%

Adapted from Wanjuu [58]

Shelf-Stability of OFSP Puree Bread

The shelf-life of bread is classified into physical, chemical and microbiological shelf-life. [59] The shelf-life of bread depends on processing, packaging, formulation and storage conditions. [60] Preservation of bread seeks to control rancidity, moisture migration, development of off-flavours, crystallization, grittiness and structural weakness in bread. [61] Preservation of white bread has been done using various preservation techniques including physical methods such as infrared, ultraviolet light, ultra high pressure (UHP) and microwave heating; chemical preservatives such as sodium acetate, acetic acid, potassium acetate among others; and bio-preservation as in the case of sour bread. [62] Advances in research are exploiting the use of nanotechnology and packaging to improve shelf-life of bread. [62] Little of this has been tested on the OFSP puree bread, but presents an opportunity of extending the keeping quality of this bread.

Stability of OFSP puree bread in storage is defined by moisture content, microbial growths and staling. [63] The microbiological and physico-chemical changes that occur in bread during storage affect the shelf-stability of the bread. The physico-chemical changes in bread result into firming of bread in a process known as bread staling.[62] Wanjuu 58 reported the shelf-life of OFSP puree bread with no added

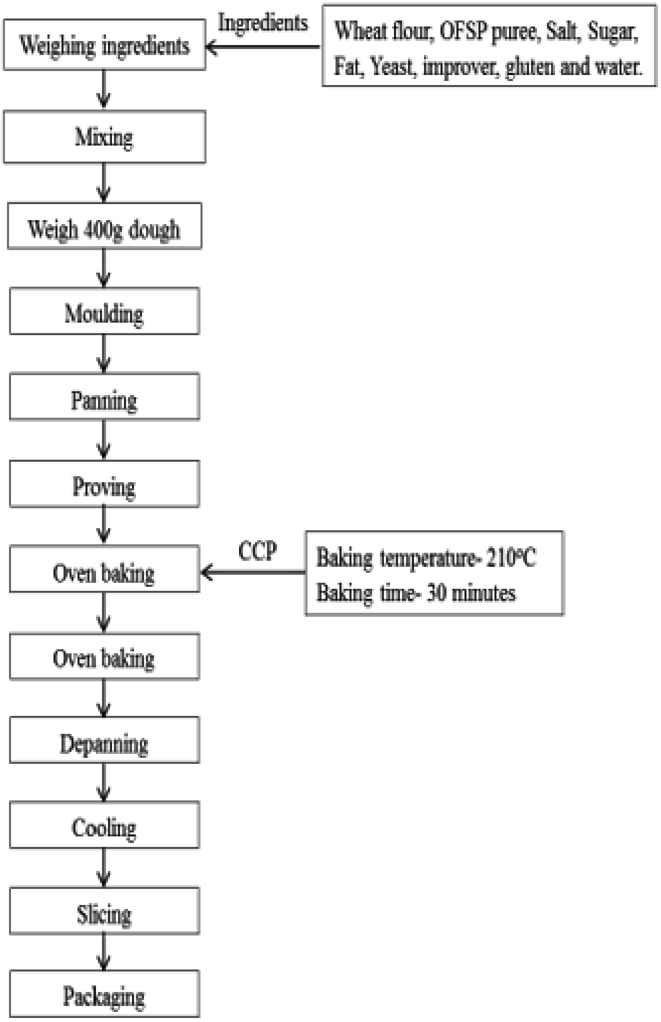

Fig. 2: Production of OFSP puree bread.

Adapted from Wanjuu[58].

chemical preservatives to be six days as compared to that of white bread that was four days. This was attributed to the lower water activity of OFSP puree bread as the water binding capacity of this bread is higher. The study also reported the greatest retention of the nutritional quality of the bread under refrigerated storage, however, the bread stale faster under such conditions.

Spoilage and Safety of Orange-Fleshed Sweetpotato Puree Bread

Baking ensures that the bacteria and mould spores which were in the flour are destroyed. [58] However, some of the bacteria spores are known to survive the heat treatment and under favourable conditions grow to cause roping of the bread. [64] *Bacillus* sp. are known to form spores which can withstand the baking process.[6,65] OFSP puree based bread is subject to microbial contamination from handling of the puree and the wheat flour. The use of contaminated ingredients such as flour or OFSP puree would easily cause microbial contamination of the bread. [66] It is, therefore, important to ensure that the raw materials are free from mycotoxin or fungal contamination to minimize the occurrence of fungal contamination in bread. Post-thermal processing contamination is also possible. [67] Proper hygiene in food handling of food processing equipment ensures limitation of microbial contamination of the product. [68] This aims at improving the keeping quality of the bread.

OFSP puree based bread also undergoes spoilage by staling which, is the commonest spoilage in bread. [69] Bread staling involves modifications of the product matrix, both the macroscopic and the molecular structures. Staling affects the firmness of the crumb, deterioration of the product flavour and softening of the crust in the macroscopic structure. [70] In the molecular structure, staling causes retrogradation and crystallinity of starch, water redistribution within the molecules of bread, decreases the amount of soluble amylose and changes the gluten (wheat protein) network and the interactions between gluten protein and starch granules in wheat bread. [63] The staling of bread is as a result of the slow change of the starch at temperatures below 55^{o}C from a moistened amorphous form to a hard less moistened crystalline form. This change causes the rapid hardening and shrinking of starch granules away from the gluten skeleton resulting into crumbliness.[71] It is important to ensure proper preservation to avoid bread staling as it results into deterioration of quality. [72]

Sensory and Nutritional Quality of OFSP Puree Bread

Promotion of OFSP roots as a functional food in India proved a succesful strategy towards eliminating VAD while cost-effectiveness is met.[73] Extending such efforts to other resource poor countries has the potential of improving nutrition status of various communities. Bread made by substituting 38% of the wheat with OFSP puree was found to be high in vitamin A (135 RAE/110 g) and had a deep-yellow colour which was highly acceptable among consumers in Mozambique.[37] Other studies done in Rwanda showed that there is great consumer preference of bread made of composite mixture of 30% OFSP-puree and 70% wheat-flour to that made of 100% wheat-flour. [74] A study by Bonsi *et al.*[75] found that 30% incorporation of OFSP puree into bread obtained the highest overall acceptability but texture had the lowest acceptability as compared to the white bread and other OFSP puree breads. The study also established that increasing the level of OFSP incorporated into bread resulted into firmer breads.

Incorporation of OFSP puree into bread baking can serve to enrich the bread energy and nutrients such as vitamins (pro-vitamin A) and minerals (Ca, P, Fe, Zn and K) and also add natural sweetness, color, flavor and dietary fiber.[19,76] The “vitabread” has a trans β-carotene content of 1.333 mg/100 g meeting about 21% of daily requirement (1,300 µg RAE/day) of nursing mothers. [44] Studies in the US have proven OFSP roots as worthy fortifying agents to help ameliorate nutritional status [77]: in SSA, the bread offers that opportunity. OFSP puree also gives the bread a golden yellow colour, thus resulting in high consumer acceptability. [34] OFSP puree bread also had desirable qualities in terms of shelf-stability, moisture content, water activity, texture and microbial growths. [58] This has encouraged its wider use as compared to OFSP flour in production of bread and other bakery products.

Marketability of OFSP-Puree Based Bread

Commercialization of a product should be demand driven rather than a push by a “champion”. Other factors can come into play in commercialization of a product such as consumers' growing awareness and demand for healthier products.[34] The OFSP puree based bread is commercially available in Kenya through selected retail chains.[17] OFSP puree bread has been in commercial production in Japan since the 1990s where it happens to be a renowned functional food consumed by a number of people.[33] A study done in Kenya to evaluate marketability of OFSP based products, showed that consumers were willing to pay for such products,[45] thus a proof of likelihood of success in adopting shelf-storable OFSP puree based bread.

A study done among consumers in Kenya revealed that the willingness to pay for OFSP puree based bread by the consumers is high owing to its nutritional value.[78] OFSP bread developed from shelf storable puree, with evaluation of its nutritional content, can have the market demand created through awareness creation.[79] With the success of marketability of shelf-storable OFSP puree based bread, the economic gains can be realized across the OFSP supply and value chains. This would be a great incentive for farmers to continue with the production of OFSP roots.

Conclusion

The use of OFSP puree in bread baking has been an avenue for food fortification and product diversification. OFSP puree based bread can enhance vitamin A intake among the population especially the consumers of products in the high end markets. Limited production and consumption of this nutritious bread is still being witnessed due to limitations resulting from the use of cold chain stored OFSP puree. The challenge posed by the use of fresh OFSP puree in the production of bread can be overcome by the use of shelf-storable preservative treated OFSP puree. However, the marketability, physico-chemical properties, shelf-stability and sensory attributes of the bread produced from the shelf-storable puree require systematic evaluation in order to establish a substantive argument for its use. With the high consumption of bread among populations, OFSP puree based bread can be part of efforts towards improving the vitamin A status of the population.

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