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Development of Low Sugar Vegetable Jam from Beetroot (*Beta vulgaris* L.): Studies on Physicochemical Sensory and Nutritional Properties

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ABSTRACT: Beetroot (*Beta vulgaris* L.) is a vegetable with high amount of biologically active substances and inorganic nitrogen. It is an ideal vegetable in making jam due to its natural deep reddish purple colour. However, utilization of beetroot for the development of value added products is still to be revealed. Therefore, the aim of the current study was to develop a low sugar jam using beetroot as a way of popularizing the vegetable jam in Sri Lanka, and to evaluate its sensory, nutritional, antioxidant and storage properties. Product optimization was done by developing beetroot jam either with mild or cooked methods and using different concentration of beetroot pulp as 50, 55, and 60% (w/w). Following the sensory analysis, the jam prepared by the mild method with 60% of raw beetroot pulp and added strawberry flavor (0.5% w/w) was selected as the best. The TSS content of the final product was found to be 46.1%, and the pH was 3.8. The results of the storage properties revealed that the developed jam can be stored under refrigerated conditions for a period of six months without addition of any artificial preservative. Therefore, it can be concluded that beetroot can be effectively used in development a low sugar extra vegetable jam successfully.

Keywords: Antioxidant activity, Beetroot, Low sugar, Sensory Evaluation, Vegetable jam

I. INTRODUCTION

Nowadays, there's a high demand for fruits and vegetables since they are a rich source of some essential dietary micronutrients and dietary fibre. Moreover, they have become an important source of phytochemicals that may benefit over many life-style related disease conditions such as cancers, cardiovascular diseases, diabetes, and etc. But, the consumption of many fruits and vegetables is limited due to their seasonality and perishability, and this leads to application of various preservation technologies including jam making.

Jam is a product of intermediate moisture that is prepared using the pulp of fruits, sugar, pectin, acid, and other ingredients which lead to keep them for a long time. A good jam has a soft even consistency, without pieces of fruits, a bright colour, good flavor, and a semi-jelled structure that is easy to spread. The traditional jam market is mainly based on various kinds of fruit jam. Due to the increase of consumer health concern, products such as low sugar and diabetic jam have been introduced to the market recently. In order to keep up with the changes in consumption practices and the presence of alternative or new products on the market, development of new products such as vegetable jam would be advantageous. There is very limited number of data on vegetable jam, since it is a new concept to the food industry. A group of Italian researches has done a study on development of vegetable jam with using carrot, and claimed that carrot can be effectively used in preparation of jam while preserving consumer acceptable sensory properties [1].

Beetroot is one of the ideal vegetables in preparation of vegetable jam due to its natural deep reddish purple colour. This intense red colour is mainly derived from high concentration of betalinin that is used as a natural colourant in food industry [2]. Other than that, betalinin is a good source of antioxidant and anti-inflammatory agent. Among the vegetables, beetroot is the vegetable with highest antioxidant activity [3], and is a rich source of phytochemicals that include ascorbic acid, carotenoids, flavonoids, and phenolic acid. When compared with other fruits, the main sugar in beetroot is sucrose, while there's only a small amount of glucose and fructose. This is preferable, especially in preparation of products like sports drinks since high fructose content reduces the exercising capacity. Other than that, beetroot juice is a rich source of many other health promoting compounds as potassium, magnesium, folic acid, iron, zinc, calcium, phosphorus, sodium, niacin, biotin, B6, and soluble fibre.

High blood pressure is a disease condition that is commonly found among many Sri Lankans, and it is a leading risk factor of cardiovascular diseases and many non-communicable diseases. Effective nutritional and lifestyle interventions are keys to prevent hypertension and related cardiovascular complications.

Recent studies suggests that dietary inorganic nitrate (NO_3^-) supplementation has beneficial effects on blood pressure control, vascular health, exercise capacity, and oxygen metabolism though targeted NO production by the bacteria presence in saliva [4]. A study from Lundberg *et al.,* [5] reported that beetroot juice is a good source of dietary NO_3^-. Moreover, in many studies, it has been proved that beetroot juice supplementation has improved exercise performance and oxygen metabolism in young healthy individuals [6]. In addition, supplementation of inorganic nitrate (NO_3^-) has been advanced as a potential, effective nutritional strategy to control blood pressure [5; 7].

Considering all of these interesting facts, and absence of vegetable jams in the local market, the objective of the present study was to introduce beetroot jam as a novel food product, and to evaluate its physicochemical, sensory, nutritional and nutraceutical benefits.

II. MATERIALS AND METHODS

A. Materials

One commercial type beetroot variety was collected from the local market, *Kamburupitiya*, Sri Lanka, and was used as the raw material for the production of all jam samples. Pectin, sugar, and all the other required ingredients in preparation of the beetroot jam were also purchased for the local market. All the other chemicals used in nutritional and shelf-life analysis were analytical grade.

B. Preparation of jam

Beetroot jam samples were prepared with different processing conditions (mild and blanched) with or without adding strawberry flavor as described by Renna *et al.*, [1] with few modifications. The best treatment among four different combinations (T1- raw beetroot with strawberry flavor, T2 – raw beetroot without strawberry flavor, T3 – blanched beetroot with strawberry flavor and T4 – blanched beetroot without strawberry flavor) was determined based on colour, aroma, taste, sweetness and spreadability using sensory analysis.

In mild method of beetroot jam preparation, beetroots were first washed, peeled, and sliced into two centimeter thickness pieces and, then blended using a food processor (Bravosimac FP500, Italy) to obtain the beetroot pulp. Beetroot jam was prepared with the production steps of cooking beetroot pulp at 80-100°C for 15 min while adding sugar (35% w/w), pectin (2% w/w), artificial strawberry flavor (0.5% w/w), and citric acid (0.5% w/w) until final brix value was reached to 46.1°Bx.

In contrast, during blanched method of beetroot jam preparation, beetroots were washed, peeled, and sliced into two centimeter thickness. Then they were blanched in 100°C for 10 min, and the blanched beetroot were pulped using a food processor.

Finally, the beetroot pulp was cooked as described in mild method of beetroot jam preparation until the final brix value of 46.1°Bx.

In order to find the best pulp concentration in beetroot jam preparation, beetroot jam with varying composition of beetroot pulp (T_A – 50% w/w, T_B – 55% w/w and T_C- 60% w/w) was developed, and the percentage of sugar added was changed accordingly.

The prepared jam samples were hot filled (85°C) in to sterilized glass jars, and immediately sealed with a cover. Then the samples were storedat 4°C until further analysis.

C. Sensory evaluation of developed beetroot jam

Two different sensory evaluations were carried out to select the best jam preparation method and the best pulp concentration by using 30 semi-trained panelists. The prepared jam samples were presented at room temperature conditions under normal lighting condition in transparent glasses coded with random three digit numbers. The colour, aroma, taste, sweetness, spreadability, appearance, and overall acceptance on each jam sample were evaluated with five point hedonic scale.

D. Proximate analysis of the selected jam sample

The proximate composition (moisture, ash, protein, fat, fibre, and carbohydrates) of the selected beetroot jam sample was done as the methods described in AOAC standards [8].

E. Determination of antioxidant activity

Raw beetroot (0.5 g) and developed beetroot jam (0.5 g) were homogenized with 100 ml of methanol, and they were centrifuged at five degrees centigrade at 5,000 rpm for five minutes. The antioxidant activity of the extracts was estimated using DPPH-radical scavenging method as described by Mishra and Chaudhury [9] with some modifications.

F. Determination of inorganic cation content

Sodium, potassium, and calcium contents of the raw beetroot and the developed jam sample were determined using the flame photometer. After ashing of one gram of each sample in a muffle furnace at 550°C for two hours, the obtained ash was cooled and dissolved in eight milliliters of concentrated HNO_3.

The filtered solution was analyzed by a flame photometer (JENWAY PEP7, UK). The standard curves were prepared using known concentrations of each inorganic cation.

G. Shelf-life analysis of the developed product

The final product selected by sensory analysis was subjected to physicochemical and microbiological analysis. The total soluble solid content (Brix model DIGT 0-80ATC, Japan) and the pH (Wagtech, Model 3305, UK) of the developed jam was measured in one month interval up to six months of period.

Moreover, enumeration of *E. coli* (Brilliant Green Bile Broth; Oxoid ltd, Basingstoke, UK), yeast and mold count Sabouraud's Dextrose agar (SDA), Oxoid ltd, UK), and the total plate count of the developed product were examined in the beginning and one month interval for a period of six months.

H. Statistical analysis

Sensory tests were conducted using completely randomized design (CRD) and samples were completely randomized across all panelists in order to avoid or minimize the effect of erroneous results occurring due to the order of samples. Results of sensory evaluations were analyzed by Kruskalwallis non parametric one-way ANOVA test using STATISTIX for Windows (version 10).The data on nutritional composition was analyzed by Turkey's test using Mini Tab software for Windows (Version 14). All the experiments were conducted in triplicate to draw statistically valid conclusions and, a probability value 5% ($\alpha = 0.05$) was used in statistical analysis.

III. RESULTS AND DISCUSSION

A. Sensory evaluation of the developed product

During this study, a primary sensory evaluation was done to determine the best pretreatment method to develop the beetroot jam. In order to achieve that, four different jam samples were developed from both mild and blanched methods either with or without addition of artificial strawberry flavor, and were subjected to primary sensory evaluation using 30 semi-trained panelists. The results of the sensory evaluation showed that there was no any significant difference ($p>0.05$) among all four types of developed jam products (Table 1). However, the jam samples produced by mild method showed the highest preference for all the tested sensory attributes with irrespective to the addition of strawberry flavor. When compared to the blanching method of jam preparation, the mild method is using less heat application in jam making process. Moreover, during the blanching method, the natural colour pigments present in beetroot can be easily leached to the used hot water which affected negatively to the colour and appearance of the prepared jam. Thus, compared to the blanching method, the mild method will preserve the natural red colour pigments present in the raw beetroot. A similar type of research on comparison of two jam making methods (mild and common method) on quality of jam prepared with carrot, the authors found that the mild method of jam making will preserve to natural colour pigments, and thus, will give higher consumer acceptance in the final product [1]. Thus, rather than the blanching method, mild method was selected as the best condition in developing beetroot jam.

Table 1: Mean rank values of the sensory evaluation of different pretreatment condition for beetroot.

Sensory Attributes	T1	T2	T3	T4
Color	$59.7^{a}\pm 0.9$	$66.7^{a}\pm 1.0$	$55.9^{a}\pm 0.9$	$51.8^{a}\pm 0.7$
Aroma	$64.1^{a}\pm 0.9$	$52.3^{a}\pm 1.1$	$66.2^{a}\pm 1.0$	$51.4^{a}\pm 0.9$
Taste	$69.0^{a}\pm 0.9$	$54.2^{a}\pm 1.0$	$54.7^{a}\pm 1.1$	$56.2^{a}\pm 1.0$
Sweetness	$72.2^{a}\pm 0.8$	$49.8^{a}\pm 1.0$	$54.4^{a}\pm 1.1$	$57.5^{a}\pm 0.8$
Spreadability	$70.1^{a}\pm 0.8$	$59.8^{a}\pm 0.7$	$47.7^{a}\pm 0.9$	$56.2^{a}\pm 0.7$
Appearance	$67.8^{a}\pm 0.7$	$63.4^{a}\pm 0.8$	$49.0^{a}\pm 0.8$	$53.7^{a}\pm 0.6$
Overall Acceptability	$71.4^{a}\pm 0.9$	$54.8^{a}\pm 1.0$	$50.4^{a}\pm 0.9$	$57.2^{a}\pm 0.6$

T1- raw beetroot with strawberry flavor, T2 – raw beetroot without strawberry flavor, T3 – blanched beetroot with strawberry flavor and T4 – blanched beetroot without strawberry flavor. Means with different superscripts in the same row are significantly different at 0.05 significance level.

Table 2: Mean rank values of sensory evaluation of jam prepared by three different beetroot pulp concentrations.

Sensory attribute	Pulp Concentration (%)		
	T_A	T_B	T_C
Colour	41.30 ± 0.87^{a}	37.83 ± 0.92^{a}	43.87 ± 1.1^{a}
Aroma	41.11 ± 0.80^{a}	35.54 ± 0.80^{a}	46.35 ± 0.92^{a}
Taste	34.80 ± 0.88^{b}	34.04 ± 0.78^{b}	54.17 ± 0.68^{a}
Sweetness	35.59 ± 0.9^{b}	35.28 ± 0.77^{b}	52.13 ± 0.72^{a}
Spread-ability	37.15 ± 1.05^{a}	39.35 ± 0.93^{a}	46.50 ± 0.80^{a}
Appearance	43.02 ± 0.70^{a}	35.78 ± 0.88^{a}	44.20 ± 0.67^{a}
Overall acceptability	33.90 ± 0.90^{a}	32.35 ± 0.71^{a}	43.25 ± 0.52^{a}

T_A- 50% w/w beet root pulp, T_B- 55% w/w beetroot pulp, T_C- 60% w/w beetroot pulp. Means with different superscripts in same row are significantly different at 0.05 significance level.

Furthermore, since the jam samples with added strawberry flavor showed the highest acceptability for all most all the tested sensory attributes, hereafter artificial strawberry flavor was added to all the prepared jam samples at a concentration of 0.5 % (w/w).

A similar research done on fruit jam suggested that addition of strawberry flavor significantly enhance the consumer acceptability of jam compared to the non-flavored jam products [10]. Thereafter, the best beetroot pulp concentration to develop a sound beetroot jam was determined by a secondary sensory evaluation using beetroot jam samples prepared with 50% (T_1), 55% (T_2), and 60% (T_3) pulp concentrations. As it is shown in Table 2, all the prepared beetroot jam samples with varying composition of beetroot pulp does not show any significant difference ($p>0.05$) for all the tested sensory attributes except for taste and sweetness. However, the jam sample with 60% (w/w) pulp concentration showed the highest mean acceptability for all the tested sensory attributes over the jam samples with 50% (w/w) and 55% (w/w) pulp concentrations. Thus, the pulp concentration of 60% (w/w) was selected as the best concentration for preparation of beetroot jam. According to the SLS standards for jam products [11], not less than 45% (w/w) of fruit ingredients should be consist in the final product to be considered it as a fruit jam, and the developed product is complying with the SLS requirements since it contains 60% (w/w) of beetroot pulp in the final product. Furthermore, according to the European Commission [12], use of 60% of the fruit pulp will lead to production of beetroot "extra jam". Also, the total soluble solid (TSS) content of the raw beetroot pulp has been increased from 8°Bx to 46.1°Bxin the developed beetroot jam, while it was 48.2°Bx in commercial low sugar strawberry jam. According to the SLS standards, the TSS of a low sugar jam should be within 45°Bxto 50°Bx.The correct sugar content is a critical factor for proper gel formation and preservation action of the jam. If the final TSS of a jam is less than 45°Bx, it will be badly reduced the shelf-life of the final product, and also the jam will have a runny consistency. In contrast, if the TSS is higher than 68°Bx, the jam will get very stiff and the sugar might start to form crystals inside the jam while affecting the texture of the final product [1]. Moreover, the European Commission has defined a jam with total soluble solids of 50% or less as a low or reduced sugar jam. Thus, since the developed product is having 60% of the beet pulp and 46.1 °Bx value, it can be claimed as a product with extra jam reduced sugar beetroot jam.

B. Nutritional quality of the developed product

The comparison of the proximate composition and the inorganic ion contents (Na, K and Ca) of the developed product and raw beetroot are presented in Table 3.

Table 3: Comparison of Nutritional composition of the developed beetroot jam and raw beetroot.

Nutrient	Composition	
	Raw beetroot	**Developed beetroot jam**
Moisture	87.4 ± 0.35^a	52.53 ± 0.80^b
Crude fat	0.3 ± 0.02^a	0.17 ± 0.01^b
Crude protein	1.35 ± 0.02^a	2.6 ± 0.03^b
Crude fibre	1.9 ± 0.01^a	3.5 ± 0.04^b
Ash	1.4 ± 0.02^a	2.93 ± 0.01^b
Minerals		
Na	28.41 ± 0.56^a ppm	13.56 ± 1.11^b ppm
K	465.26 ± 8.00^a ppm	223.78 ± 2.32^b ppm
Ca	59.23 ± 3.56^a ppm	65.98 ± 3.81^b ppm

Potassium can be regarded as the most important ion in beetroot considering its mineral composition. The potassium content in developed beetroot jam reduced significantly by about 50% w/w when compared with the raw beetroot. According to Schroth *et al* [13], the reduction in potassium content is probably due to leaching during boiling of beetroot. Similar type of results was obtained by Renna *et al* [1] in a research on preparation of carrot jam by common method where carrots were boiled for 15 min. In contrast, they found that the reduction of potassium was low in mild method in which the cooking time was reduced to 5 min. Similarly, in the current study, following of blanching could help to retain much potassium content in the end product. But, unfortunately, due to the less consumer preference, use of the blanching method was not a suitable pretreatment in preparation of beetroot jam.

Moreover, when compared to the raw beetroot, sodium content of the developed product was found to be reduced slightly, and in contrast, a slight increment of the calcium content was observed.

C. Antioxidant activity of the developed product

Beetroot is an outstandingly rich source of antioxidants. According to a study done by Wootton-Beard *et al* [14] the antioxidant capacity of beetroot juice is comparatively higher than that of many fruits and vegetables. Moreover, they have reported that the antioxidant capacity of beetroot juice in both DPPH and FRAP methods are far greater than well-known antioxidant rich vegetables such as tomato and carrot, and fruits such as orange and pineapple.

The DPPH radical scavenging inhibition percentage of beetroot was found to be 50.35%, and that of the developed jam was reduced up to 32.97%.

The significant reduction of antioxidant activity during the jam making could be resulted due to the exposure of beetroot pulp for prolonged heat condition. In contrast, as it was reported by Renna *et al* [1], the antioxidant activity of jam made by mild heat treatment method was found to be reduced slightly from that of raw carrot, while in purple jam it was found to be increased by 44%. Furthermore, they found that the carrot jam prepared by cooking the carrot for 30 min resulted loss of its antioxidant activity significantly than the raw carrot, and the results of the present study are in agreement with findings of Renna *et al*., [1), where 34.5% reduction in the antioxidant activity of the produced jam was found when compared to the raw beetroot.

D. Shelf-life analysis of the developed product

Generally, indicator organisms such as *E. coli* can be used to estimate the potential safety and quality of a food product [15], and it was found that the developed product was free from *E. coli* throughout the storage period. Furthermore, both total plate count and the yeast and mold counts of the developed product were found to be $<10^2$ CFU/g during its storage under refrigerated conditions for six months, and the results were in accordance with Indian Food Regulations for Jam, marmalade, fruit jelly, fruit chutney and sauces [16]. Thispreservative action in jam is mainly due to its high sugar content and the production of invert sugar by the high heat treatment. The produced invert sugar will reduce the hydrophylicity and crystalising ability of sugar, and thus, improves the storage life of jams. In addition, as it is described previously, reduction of the TSS content of less than 45°Bx, the shelf life of the product will reduced considerably. Conversely, the TSS content of the developed product was found to be 46.1°Bx, and it was in the safe limit. Moreover, acidic nature of the fruits and the added citric acid are adding a preservative effect by reducing the pH of the product. Generally, in order to control the growth of *botulinum* and other types of microorganisms in products like, jams, jellies and, marmalades, they should contain enough acid to have a pH of 4.6 or lower. The pH of the developed beetroot jam was found to be 3.8 while that of commercial low sugar strawberry jam was found to be 3.4. Thus, even though any artificial preservative was not added to the developed product, it could be successfully stored under refrigerated conditions for a period of six months without opening the bottle. Furthermore, this storage life could be extended by adding permitted preservative under permitted level.

IV. CONCLUSION

The low sugar vegetable jam prepared using raw beetroot pulp with flavor and 60% (w/w) beetroot pulp concentration had higher mean rank values for sensory properties of appearance, color, aroma, taste, sweetness, spread-ability, and, overall acceptability compared to other jam samples.

According to the microbiology analysis, the shelf-life of the developed product was reported to be six months under refrigeration condition without adding any artificial preservatives. Finally it can be concluded that beetroot can be successfully used to develop a vegetable jam to replace fruit jams.

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