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Research Paper

Production of health-friendly, ready-to-serve fruit drinks from under-utilized local fruits from Sri Lanka

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Abstract: Five under-utilized fruits, namely Mauritius Plum (*Flacourtia inermis* Roxb.), Ceylon Olive (*Elaeocarpus serratus* L.), Tamarind (*Tamarindus indica* L.), Woodapple (*Limonia acidissima* L.) and Soursop (*Annona muricata* L.) were used to produce Ready-To-Serve Fruit Drinks (RTSFDs) while preserving the physical, nutrient and functional properties of the original fruits. The products were developed without added artificial colour, flavour or preservative, but with required shelf-life suitable for market circulation and to ensure high consumer acceptance as a tasty and healthy natural drink. Successful extraction of natural colour, aroma and flavour of the fruits into water was a success with high consumer acceptance. Safe preparation method, maintenance of high acidity levels and safe packaging helped to achieve a long shelf life of 18 months. The newly developed RTSFDs were cost effective and also received high scores on sensory parameters (taste, odour, colour and overall acceptability). Nutritional parameters of RTSFDs such as carbohydrates, protein, total fat and minerals were in the range of 5.98 – 8.22, 0.01- 0.38, 0-0.18 and 1.00 – 1.86 g/100 ml, respectively. Vitamin C, total phenolic content and antioxidant activity of RTSFDs ranged between 0.15 – 0.70 mg/100 ml, 12.53 - 14.57 GAE mg/100 ml and 6.11 – 7.23, respectively. The production cost of RTSFDs of Mauritius Plum, Ceylon Olive, Tamarind and Woodapple ranged between Sri Lanka Rs 40–50 per unit (250 ml in sealed returnable glass bottle) with a profit margin varying from Rs. 31-39 per unit. Product of Soursop had the highest production cost with the lowest profit margin. Hence, the newly developed RTSFDs could be categorized as low-cost, healthy natural beverages.

Keywords: Value addition, under-utilized fruit extractions, ready-to-serve fruit drinks

Introduction

Fruits contain important nutrients and phytochemicals, and are an essential component of balanced and healthy diets. They contribute to nutritional security and provide key elements such as vitamins, minerals, essential micro-nutrients, fibre, vegetable proteins, carbohydrates and bio-functional components. (WHO and FAO, 2004). Tropical fruits are important to developing countries from both nutritional and commercial perspectives. By nutritional and extra-nutritional compositions, fruits have been categorized as super-fruits to promote some of the lesser known tropical fruits and fruits, which do not have worldwide popularity (FAO, 2013). Tropical fruits are a relatively cheap and a ready source of vitamins and minerals which are important nutritional components of the human diet (ITFN, 2014). Fruits are also excellent sources of phenolic compounds, which impart health benefits beyond basic nutrition (Haminiuk *et al*., 2012).

Besides the commonly consumed fruits, some under-utilized fruits are known in traditional foods, especially in rural communities. They could be antioxidant sources compared to commercial fruits (Sirasa *et al*., 2014; Silva and Sirasa, 2016). A number of underutilized fruits are adequately rich in antioxidants and phytochemicals besides necessary nutritional components such as vitamins, minerals and dietary fibre (Mallawaarachchi *et al*., 2015).

Many authors have highlighted the importance of these fruits, reporting their nutritional contents and health-beneficial components and have suggested possible value-added products from them (Ediriweera, 1999; Gunasena and Pushpakumara, 2007; Medagoda and Perera, 2007; Peiris, 2007; Rathore, 2002; Wickremasinghe, 2004; Wilson Wijeratnam, 2002). Some of the traditional fruits in the tropical region are not only rich in nutritional properties, but also contain bioactive components and could be classified as functional foods (Wijeratne, 2013). Due to the broad spectrum of their flesh and skin colour, the under-utilized fruits may have potential benefits to human health (Ismail and Azlan, 2015). Along with phenolic compounds, other antioxidant components such as vitamins C and E and Carotenoids could also contribute to the antioxidant capacity of under-utilized fruits. Fruits that has sour and bitter tastes are known to exhibit high antioxidant capacity (Ikram *et al*., 2009; Prakash *et al*., 2013).

Sri Lankan native fruits and vegetables are still being used in traditional indigenous medicine. These are rarely eaten, unknown and unfamiliar and have not been received much attention and thus, categorized as under-utilized fruits. They are under-utilized due to lack of popularity among local communities and lack of information on nutritional compositions and physical qualities (Sirasa *et al*., 2014; Silva and Sirasa 2016).

As most of the tropical/under-utilized fruits have a very short life span as fresh fruits, they need to be processed to extend their shelf-life, to reach the consumer (Wijeratne, 2013). Many authors have reported less popularity of under-utilized fruits among consumers due to some typical characteristics of these fruits such as fibrous flesh, sour taste due to high acidity, astringency, bitterness, and strong smell, and have suggested the preparation of alternative food products from them with necessary nutritional qualities (Wijeratne, 2013; Ikram *et al*., 2009). The processing of under-utilized fruits is a neglected area, which needs attention. As these species are not grown widely, fruit production is low and commercial level processing industries cannot be operated as there is no constant supply. In this scenario, it is necessary to develop low cost processing technologies for these crops (Abeyrathne and Jaenicke, 2006; Pushpakumara *et al*., 2007). Successful value-added products development from different under-utilized fruits has been reported (Rathore, 2002; Vijaykumar *et al*., 2013).

Fruit juice is a growing beverage category in Sri Lanka, driven by people’s desire to lead a healthy life. Ready-To-Serve (RTS) fruit drink is a drink intended for consumption without dilution and could be prepared from unfermented or fermentable fruit juice/puree/concentrate containing any soluble sweetener and potable water. The product shall be processed by heat in an appropriate manner before or after being sealed in a container. Aromatic substances, volatile flavor/aroma components, pulp and cells must be recovered from the same kind of fruit and be obtained by suitable physical means (SLSI, 2010).

Consumers preferred fruit drinks over other beverage varieties. Thus, expansion of fruit drink industry in Sri Lanka is approved by the authorities instead of carbonated drinks. The reasons, which impacted the choice of fruit drinks were its health benefits, taste and the ability to put off thirst and hunger. Accordingly, there is a wide opening for the fruit drinks market to improve in future (Rambukwella *et al*., 2015).

The Development Policy Framework of the Government of Sri Lanka (DNP, 2010) highlighted the promotion of natural drinks/fruit juices instead of carbonated soft drinks among people. A Fruit Research Programme has been launched by the Department of Agriculture, Sri Lanka and post-harvest handling and production of fruit based products are priority sections of this Program (DOA, 2014).

Commercial RTS drinks available in the market in Sri Lanka could be categorized as essence-based beverages introduced mainly by multi-national companies, fruit drinks prepared with imported pulps and fruit drinks manufactured from locally available fruit varieties. Most of these fruit drinks are prepared using commonly consumed commercial fruit varieties and usually with chemical colours, flavours and preservatives (Thillakawardane, 2009). Present growth in consumer demand for natural food products has increased the need for preparation of food products without artificial/chemical agents and when necessary, with coloring/flavoring and other purpose compounds only from natural sources.

Considering the above facts, an attempt was made to develop RTS fruit drinks (RTSFDs) as low-cost, tasty and health-friendly natural drinks from five locally available under-utilized fruits. The main objectives of the product development were to preserve physical, nutrient and functional properties of the original fruits, to avoid any artificial colour, flavour or preservative and to maintain a long shelf-life.

Materials and Methods

Optimization of fruit extraction method for Ready-To-Serve Fruit Drink (RTSFD)

Ripe fruit samples of Mauritius Plum (*Flacourtia inermis* Roxb.), Ceylon Olive (*Elaeocarpus serratus* L), Tamarind (*Tamarindus indica* L.), Woodapple (*Limonia acidissima* L.) and Soursop (*Annona muricata* L.) of the correct stage of maturity were collected from backyard gardens in Kandy and Anuradhapura Districts of Sri Lanka and transported to the laboratory of Food Research unit, Department of Agriculture. All samples were cleaned, washed and made suitable for extraction. From each fruit, three types of samples were prepared namely, (a) Mauritius Plum and Ceylon Olive – whole fruit, crushed fruit, fruit blended into pulp were taken as treatments, (b) Tamarind and Soursop – flesh with seeds, flesh deseeded and deseeded flesh blended into pulp had been used as treatments and (c) Woodapple – flesh with seeds, flesh deseeded and flesh blended with seeds were the treatment components.

One kilogram of fruits/fruit mass from each fruit and three liters of 12° Brix sugar solution were used for extraction. Each treatment/sample was immersed in sugar solution and heated up to 100 °C. Extraction time of fruits/fruit masses in boiling sugar solution was one hour. Extractions were kept in ambient temperature for eight hours, strained and used for RTSFD preparation.

Preparation of RTSFDs from the relevant fruit varieties

The filtered extractions were filled into 250 ml glass bottles by hot-filling and sealed with crown caps. Bottles were pasteurized for 15 min by immersing them in boiling water. The RTSFDs were produced in accordance with the specifications/ hygienic aspects determined by the Sri Lanka Standard Institution (SLSI, 2010).

Determination of the physical parameters of RTSFDs

Colour, aroma, taste and consistence of each treatment prepared using five different fruits were studied using sensory evaluation. The fruit content was recorded as a percentage (%).

Analysis of the Chemical properties of RTSFDs

The titratable acidity was determined by using 10 ml of the sample with 0.1 N NaOH in the presence of Phenolphthalein indicator. The Brix values were recorded using a hand refractometer (ATAGO-HSR-

500) and pH was determined using Nippon pH meter.

Evaluation of the Microbiological parameters of RTSFDs

Serial dilutions were made for each sample and the plates were incubated at 32 °C. The colonies were counted using a Colony counter. Total plate count, Coliform count and yeast/mould count of the liquids were recorded by following SLSI recommendations (SLSI, 2010).

Determination of the nutritive components of RTSFDs

The proximate analysis of the samples for moisture, ash and carbohydrate contents were determined as described by the AOAC (2005). Crude protein and total fat contents were determined according to the method proposed by Pearson (1976). Vitamin C and vitamin A were determined by the methods described by AOAC (1990). Energy levels of RTSFDs were estimated accordingly.

Analysis of antioxidants content in RTSFDs

Antioxidant parameters and total phenolic compounds were quantified using Folin-Ciocalteu assay according to the method developed by Velioglu *et al*. (1998). The antioxidant activity was recorded using the 2,2-diphenyl-1-picrylhydrazyl free radical (DPPH) scavenging assay described by Lai *et al*. (2001).

Sensory Evaluation and Consumer acceptance of RTSFDs

Sensory evaluation of RTSFDs was done with a 10-member trained panel. In addition, the samples were subjected to sensory evaluation by untrained panelists belonging to different social/community groups, each consisting of 30 members. Consumer acceptance status was also analyzed based on the results of sensory evaluation involving different social groups.

Estimation of the shelf-life of RTSFDs

Shelf-life of the RTSFDs was estimated using the microbiological tests and sensory evaluation on physical parameters. The RTSFDs were kept in ambient temperature for 18 months period, and microbiological tests and sensory evaluations were conducted after every three months during the storage period.

Cost of production and profitability of RTSFDs

Cost of production of RTSFDs and profitability were calculated based on the costs involved in the production process and possible sale price in comparison with the similar type of beverages available in the market. The wholesale price of the five fruits varied depending on the availability, seasonality, popularity and other specific characteristics of the fruit. Cleaned weight depended on the weight of edible part of the fruit. Cost of the cleaned fruit was accordingly considered as the cost of the edible part of the fruit. Quantity of sugar for the extraction was used according to the Brix value determined for the fruit. Interim Production cost was calculated on the basis of the cost of the cleaned fruit (kg) and sugar used for the preparation of 3 L of RTSFDs. Final Production cost involved the cost of cleaned fruit (1 kg), cost of the quantity of the sugar used for preparation of 3 L of RTSFDs and other related costs (labour, gas, handling charges, transport, package).

Statistical analysis

The experiment was conducted in complete randomized design with five replicates. All parametric data were analyzed using ANOVA and non-parametric data were analyzed using Kruscal Wallis test at p=0.05.

Results and Discussion

Fruit extractions obtained from different fruit samples exhibited varying characteristics of colour, consistence and taste (Table 1). The characteristics of extracts changed among the fruit types used and with the treatment within each fruit category. The overall acceptability of the extractions was determined by a sensory evaluation (Table 2) and the best extraction was obtained accordingly.

Table 1. Characteristics of extractions obtaining from different samples of five fruit types

Fruit	Sample/Treatment (in 12° Brix sugar solution)	Characteristics of the extraction		
		Colour	Consistency	Taste
Mauritius Plum	Whole fruit	Bright red	Clear solution	Sweet/Sour (prominence–sour)
	Crushed-fruit	Reddish pink	Solution with deposit	Sour
	Fruit blended into pulp	Dull pink	Thick liquid	Sour
Ceylon Olive	Whole Fruit	Colourless	Clear solution	Mild sweet
	Crushed fruit	Light yellow	Clear solution	Mild sweet
	Fruit flesh blended into pulp	Greenish yellow	Clear solution	Sweet and Sour
Tamarind	Flesh with seeds	Light brown	Clear solution	Sweet & Sour (prominence–sour)
	Flesh deseeded	Light brown	Clear solution	Sweet & Sour (prominence–sour)
	De-seeded flesh blended into pulp	Light brown	Clear solution	Sweet & Sour (prominence–sour)
Woodapple	Flesh with seeds	Brown	Clear solution	Sweet & Sour
	Flesh de-seeded	Brown	Clear solution	Sweet & Sour
	Flesh blended with seeds	Dull brown	Mildly-thick liquid	Sweet & Sour with bitterness
Soursop	Flesh with seeds	Colourless	Clear solution	Mild sweet
	Flesh de-seeded	Colourless	Clear solution	Mild sweet
	De-seeded flesh blended into pulp	Colourless	Clear solution	Sweet & Sour

Based on the sensory properties tested (Table 2), the extraction using whole fruits of Mauritius Plum was rated significantly higher ($P<0.05$) than those obtained with other two samples. Pigments of the skin of Mauritius Plum could be successfully extracted when the whole fruit was used to develop bright red colour with sweet and sour taste (Table 1) with the highest acceptability. When the fruit skin was damaged (in crushed fruit and fruit pulp), pink coloured flesh particles were blended into the solution, making the extraction a thick liquid having unfavorable colour, mouth feeling and taste. Hence, the acceptability of those extractions was poor (Table 2).

In the case of Ceylon Olive, sensory properties of the extraction obtained by blended fruit flesh into pulp showed significantly higher sensory attributes on colour, consistency, taste and overall acceptability. With similar characteristics shown in the extracts, sensory evaluation showed that there is no significant difference ($p<0.05$) among the three Tamarind samples (Tables 1 and 2).

In the case of Woodapple, the extraction obtained from the blended pulp with seeds received the lowest scores in all sensory attributes. No significant difference was shown in extractions of Woodapple flesh with and without seeds ($p<0.05$). Colour and consistency of Soursop extractions of the three samples also showed no significant difference. However, the quality of the extract was improved, together with taste and overall acceptability, when the de-seeded pulp was used for extraction.

Based on the results of the sensory evaluation, the best extraction for each fruit was selected for RTSFD production from each fruit. The selected samples are shown in Table 3. In the case of Tamarind, the sensory evaluation showed no significant difference in three treatments used and hence, the extraction of flesh with seed without blending was selected for preparation of RTSFD as there was no extra cost involved for seed removal. Woodapple flesh with seeds was also selected based on the same criterion.

Table 2. Sensory properties of different fruit extractions

Fruit	Sample/Treatment (In 12° Brix sugar solution)	Scale* readings on characteristics of the extraction			
		Colour	Consistency	Taste	Overall acceptance
Mauritius Plum	Whole fruit	9.0	9.0	9.0	9.0
	Crushed fruit	6.6	7.6	7.4	5.3
	Fruit blended into pulp	4.3	6.3	7.8	4.9
	P value	<0.05	<0.05	<0.05	<0.05
Ceylon Olive	Whole fruit	5.4	7.2	5.2	5.6
	Crushed fruit	7.3	7.8	7.9	7.3
	Fruit blended into pulp	9.3	8.7	9.0	9.0
	P value	<0.05	<0.05	<0.05	<0.05
Tamarind	Flesh with seeds	8.1	8.0	8.0	8.3
	Flesh deseeded	8.0	8.0	8.0	8.2
	De-seeded flesh blended into pulp	8.0	8.1	8.0	8.2
	P value	NS**	NS	NS	NS
Woodapple	Flesh with seeds	8.1	9.0	9.0	9.0
	Flesh deseeded	9.0	9.0	9.0	9.0
	Flesh blended with seeds	6.3	6.8	7.2	6.7
	P value	0.05	0.05	0.05	0.05
Soursop	Flesh with seeds	8.4	8.0	7.1	7.3
	Flesh deseeded	8.4	8.2	7.3	7.8
	De-seeded flesh blended into pulp	9.3	8.0	9.0	9.0
	P value	NS	NS	0.05	0.05

* Hedonic Scale: 1 = Very poor; 9 = Excellent; ** NS = Not significant (p>0.05)

Table 3. Accepted extraction methods for different fruits for preparation of RTSFDs

Fruit	Sample/Treatment*
Mauritius Plum	Whole fruit
Ceylon Olive	Fruit flesh blended into pulp
Tamarind	Fruit flesh with seeds
Woodapple	Fruit flesh with seeds
Soursop	De-seeded fruit flesh blended into pulp

*In 12° Brix sugar solution. Extraction time: 1 h in boiling solution

The extractions of all five fruits were prepared using 12° Brix had sweet and sour taste, but had prominent sourness. Due to higher acid content, sweetness of these fruits was naturally low. Based on sensory properties, adjustments were made to balance the sweet/acid taste where higher levels of sugar were added to maintain the sugar/acid ratio of RTSFDs.

Table 4 shows the adjusted Brix values suitable for the production of RTSFDs.

<u>Sensory evaluation of RTSFDs on physical parameters</u>

The results of the sensory evaluation of RTSFDs developed using selected fruit extracts (Table 4) are presented in Table 5. The fruit content (%) of the each product was also determined.

Table 4. Brix values for different extracts of fruits for the production of RTSFDs

Extract	Brix value
Mauritius Plum	21°
Ceylon Olive	18°
Tamarind	21°
Woodapple	18°
Soursop	15°

Table 5. Results of the sensory evaluation of RTSFDs for physical parameters

Parameter	Fruit variety					
	Mauritius Plum	Ceylon Olive	Tamarind	Woodapple	Soursop	P value
Colour	9.0	8.5	8.0	8.0	7.0	<0.05
Aroma	6.8	8.0	7.3	8.1	6.8	<0.05
Taste	8.3	8.6	7.9	8.2	7.6	NS*
Consistency	9.0	7.8	7.1	8.0	7.3	<0.05

*NS=not significant (p>0.05)

As depicted in Table 5, the colour of all RTSFDs received high acceptability where the product of Mauritius Plum secured the highest score for colour compared to all other products. Soursop, however obtained the lowest score on colour due to off-white colour. The RTSFDs developed from Ceylon Olive and Woodapple obtained the highest scores on aroma while the products developed from Mauritius Plum and Soursop received the lowest scores, probably due to being soft or lack of aroma in the latter. The high acceptability of extracts was due to the presence of natural taste of each fruit in the extractions that might have been further improved with the added sugar in RTSFDs. However, there was no significant difference in the taste attribute (p>0.05) of all RTSFDs. All the RTSFDs received favourable scores for consistency indicating that all products were with light deposit, which creates good mouth-feeling. The product of Mauritius Plum secured the highest consistency score as it did not contain any pulp and produced the mouth feeling of a commercial beverage. The levels of fruit content in the extractions was lowest in RTSFD developed with Mauritius Plum indicating that the product contained only the pigments and a certain percentage of acids making it a transparent solution.

Chemical parameters of RTSFDs

Chemical properties of RTSFDs produced using five fruits are given in Table 6. All RTSFDs showed high Titratable acidity as five fruits used in this study contain large quantities of acids (tartaric acid, citric acid, etc.) and acetogenins. Accordingly, the pH values of RTSFDs were in the range of 2.48 – 3.75 (Table 6), and were within the range allowed for RTSFDs. Because of the high levels of acids present in the fruits, high quantities of sugar had to be added to mask the acidity of the final products. Mauritius Plum and Tamarind required the very high level of sugar to maintain sensory properties (as indicated by Brix values). Soursop, however, showed the minimum acidity and hence the required quantity of sugar was less.

Table 6. Chemical Properties of RTSFDs

Parameter	Fruit variety					
	Mauritius Plum	Ceylon Olive	Tamarind	Woodapple	Sour-sop	P value
Titratable acidity	0.83	0.85	0.73	0.87	0.70	<0.05
Brix^{o}	21	18	21	18	15	<0.05
pH	2.48	3.75	3.53	3.12	3.75	<0.05

Microbiological parameters of RTSFDs

The absence of microbial counts in the final product in terms of total plate count (cfu/g), Coliform count (cfu/g) and yeast/mold count (cfu/g) indicated that the methodology of preparation of RTSFDs, which included heating of the fruits/fruit masses in sugar solution up to 100 °C and keeping the same in boiling for 1 h, hot filling into glass bottles, pasteurization of the bottles for 15 min and storing in crown-capped glass bottles in ambient temperature have helped in maintaining hygienic properties of the product. In addition, the high acidity levels of all RTSFDs could have helped to maintain sterilized condition of the product in the package.

Nutritional parameters of RTSFDs

Nutritional properties of the RTSFDs are given in Table 7. The nutritional parameters of the newly developed products were comparable with those identified for diluted fruit extractions. Carbohydrate levels were noticeably high, due to the presence of sugars in fruits and also due to added sugar (sucrose).

Vitamin C levels are low in the products as the RTSFDs are prepared by heat-extraction method. All RTSFDs contained 1.0 mg or more of minerals, probably owing to the high mineral contents found in under-utilized fruits.

Table 7. Nutritive components of RTSFDs (100 ml)

Parameter	**Fruit variety**				
	Mauritius Plum	**Ceylon Olive**	**Tamarind**	**Woodapple**	**Soursop**
Carbohydrates (g)	5.98	6.60	8.22	5.75	6.93
Protein (g)	0.01	0.08	0.15	0.38	0.18
Total fat (g)	0.09	0	0	0.18	0
Vitamin C (mg)	0.70	0.80	0.15	0.15	0.23
Vitamin A (mcg)	0	0	0.3	1.5	0.4
Minerals (mg)	1.00	1.86	1.45	1.36	1.12
Energy (kcal)	24.45	26.45	33.6	26.1	28.3

Antioxidants in RTSFDs

Total phenolic content and antioxidant activity in different fruit extractions are shown in Table 8. The total phenolic content in the RTSFDs varied from 12.53 to 14.57 GAE mg/100 ml. The Antioxidant activity of the RTSFDs was ranging between 6.11 - 7.23%. Results did not indicate a wide variation in phenolic content and antioxidant activity among the RTSFDs from different fruits. The RTSFDs contained a satisfactory levels of phenolic content and antioxidant activity. The total phenolic content in RTSFDs was however, low compared to the same of the fresh fruit.

Table 8. Antioxidant Parameters of RTSFDs

Parameter	**Fruit variety**				
	Mauritius Plum	**Ceylon Olive**	**Tamarind**	**Woodapple**	**Soursop**
Total Phenolic content (GAE mg/100 ml)	13.87±3.2*	12.80±1.0	14.11±2.5	14.57±2.1	12.53±2.1
Antioxidant Activity (%)	7.20±0.1	6.66±0.1	7.23±0.2	6.91±0.5	6.11±0.1

*Values presented are mean±standard error

Consumer acceptance of RTSFDs

The factors that affect consumption and the purchasing decisions are also related to the consumer acceptance. The socio-demographic properties play a certain role in the demand for food and respective buying behaviours (Rambukwella *et al*., 2015; Sabbe *et al*., 2009). The results of the sensory evaluation of RTSFDs involving different social groups are shown in Table 9.

Odour, colour and overall acceptability of RTSFDs of Mauritius Plum, Ceylon Olive, and Soursop had satisfactory ratings and also were not significantly different (p>0.05) from each other. The RTSFDs of Woodapple and Tamarind received lower ratings, which may be connected to the specific taste of the fruits that is not familiar to this group of people.

Table 9. Sensory properties of different RTSFDs determined by different social groups

Sensory property	Fruit variety					
	Mauritius Plum	Ceylon Olive	Tamarind	Woodapple	Soursop	P value
Children up to 5 years						
Taste	7.2	7.0	7.0	7.0	7.1	NS*
Odour	6.8	6.9	7.1	7.3	7.5	NS
Colour	7.3	6.8	7.2	7.6	6.7	NS
Overall acceptability	7.2	6.8	7.4	7.8	6.8	NS
Young to middle aged						
Taste	8.1	8.3	8.9	8.7	8.1	NS
Odour	8.0	8.2	8.7	7.8	7.9	NS
Colour	8.5	7.8	7.8	8.0	7.7	NS
Overall acceptability	8.4	8.1	8.1	8.2	7.8	NS
Above 60 years						
Taste	7.8	8.3	7.9	7.9	8.1	NS
Odour	7.6	8.3	7.8	7.7	7.9	NS
Colour	8.3	7.8	7.8	7.6	7.5	NS
Overall acceptability	7.7	8.2	7.8	8.2	8.3	NS
Small food-outlets consumers						
Taste	7.8	7.8	7.7	8.0	8.1	NS
Odour	8.0	8.1	8.0	7.6	7.9	NS
Colour	8.1	7.8	7.6	7.9	7.7	NS
Overall acceptability	8.0	8.3	7.8	8.2	8.1	NS
Educated/working persons						
Taste	8.2	9.0	8.0	9.0	8.6	NS
Odour	7.8	7.7	7.9	8.6	7.9	NS
Colour	8.8	8.1	8.2	8.0	7.6	NS
Overall acceptability	8.5	8.3	8.0	8.5	8.1	NS
Foreigners						
Taste	7.5	6.7	6.8	6.5	7.1	NS
Odour	7.0	6.7	7.1	6.6	6.9	NS
Colour	8.5	8.1	8.0	7.7	8.0	NS
Overall acceptability	7.2	7.3	7.3	7.0	7.4	NS

*NS=not significant (p>0.05)

Evaluation of sensory properties of five RTSFDs by the six different social groups showed satisfactory ratings for taste, odour, colour and overall acceptability. Comparatively low ratings received for Mauritius Plum and Tamarind by certain social groups could be attributed to prominent acid taste of those products. The RTSFDs of Woodapple and Tamarind, in particular, received lower ratings by the group of foreign panellists. This rating could be due to specific taste of the fruits, which is not familiar to this group of panellists.

Shelf-life of RTSFDs

Negative results were obtained for microbiological evaluations (data not presented) indicating that a sterilized condition has been maintained in all five

RTSFDs throughout the period of 18 months. Results of the sensory evaluation after 3 months of storage of the RTSFDs are presented in Table 10. Taste, odour, colour and overall acceptability of all RTSFDs received satisfactory ratings by trained panellists for evaluations conducted at 3 (Table 10), and 6, 9, 12, 15 and 18 (data not presented) months of storage of the five RTSFDs. There was a marginal declining of sensory properties observed after 3 months. The results indicated that all products were in acceptable quality during the storage period of 18 months.

Ratings on sensory parameters of different RTSFDs were also not significant (p>0.05). Based on the results of microbiological tests and sensory evaluation (Tables 10), the shelf life of RTSFDs could be estimated as 18 months.

Table 10. Sensory evaluation of RTSFDs after 3 months of storage

Parameter	**Ready-To-Serve Fruit Drink Type**					
	Mauritius Plum	**Ceylon Olive**	**Tamarind**	**Woodapple**	**Soursop**	**P value**
Taste	8.0	8.1	8.0	8.5	8.0	NS*
Odour	7.8	7.2	7.0	6.8	7.3	NS
Colour	8.8	7.8	8.0	8.2	7.2	NS
Overall acceptability	8.4	8.1	8.0	7.6	7.4	NS

*NS=not significant (p>0.05)

Cost of production and profitability of RTSFDs

Costs of production of RTSFDs and profitability, which were determined by sales of the product in relevant outlets are presented in Table 11**.** The final production cost of RTSFDs of Mauritius Plum, Ceylon Olive, Tamarind and Wood apple was in the range of Sri Lanka Rs 40-50.

Production cost of one unit of RTSFDs of Soursop was high as the price of the fresh fruit was considerably high resulting in a low profit margin with the sale price of Rs 80 per unit. Considering the health benefits of Soursop fruit, a higher sale price per unit could be received.

Table 11. Average Cost of Production of one unit of RTSFDs and profitability

Cost/price components[1]	**Ready-To-Serve Fruit Drink Type**				
	Mauritius Plum	**Ceylon Olive**	**Tamarind**	**Woodapple**	**Soursop**
Wholesale price (Rs*/kg)	45.00	100.00	100.00	60.00	200.00
Cleaned weight obtained from 1 kg	0.90	0.88	0.80	0.50	0.65
Cost of cleaned fruit (Rs/kg)	50.00	113.60	125.00	120.00	307.70
Cost of cleaned fruit + Sugar in 3 L solution (Rs)	113.00	167.60	188.00	174.00	352.70
Interim Production Cost per Unit (Rs)[2]	11.30	16.75	18.80	17.40	35.30
Final Production cost: per Unit (Rs)[3]	41.30	46.75	48.80	47.40	65.30
Profit per unit (Rs)	38.70	33.25	31.20	32.60	14.70

* Rs = Sri Lanka Rupees (1 Rs = 158 USD)

1 The different cost/price components considered for calculations: Price of sugar = 100 Rs/kg, Cost of Labour = 187.50 Rs/h; Cost of Gas + handling charges + transport + package = 15 Rs/Unit, where 1 Unit = 250 ml of RTSFD in sealed returnable glass bottle; Sale price of 250 ml bottle of RTSFD = Rs 80.00; Number of units produced from 3 L sugar solution + 1 kg fruit = 10

2 Interim Production cost (Rs) = Cost of cleaned fruit + Sugar in 3 L solution

3 Final Production Cost (Rs) = Interim Production cost + Gas + labour + handling charges + transport + package

Conclusion

Natural colour, aroma and flavour of the five under-utilized fruits tested could successfully be taken into water extractions. High acidity level of extracts could be balanced with sweetening agent to maintain desirable sensory properties with high consumer acceptance in final Ready-To-Serve Fruit Drinks (RTSFD) products. The method of preparation and high acidity levels of extractions contributed to achieve long shelf-life of 18 months. As these RTSFDs were produced only with natural ingredients, contain necessary nutritive components with functional properties, and are free of health-hazardous additives, they can be categorized as health-friendly natural fruit drinks. Production of these RTSFDs is profitable and hence, commercial scale production can be recommended. Further development of these RTSFDs could be conducted to find possibilities of neutralizing a certain percentage of acids present in extractions and using low-energy non-nutritive sweeteners.

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