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(RESEARCH ARTICLE)

Chemical, physicochemical analysis and sensory evaluation of the novel formulation of tea based (*Camellia sinensis* L.) natural carbohydrate-electrolyte replenishing drink (sports drink)

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Abstract

Sports drinks are consumed as a nutritive supplement by the sportsmen. Artificiality of those formulations, increases the unreliability over the consumers regarding health effects. The created objectives were formulated, tea based sports drinks by using Ceylon tea which matches the plasma osmolality. Sensory evaluations were done to investigate the market position and the performance of tea based sports drinks and results demonstrated a higher consumer preference on tea based sports drinks than that of commercially available drinks. To reveal the health benefits, total phenolic content (TPC), total flavonoid content (TFC), total antioxidant capacity (TAC) and content of catechins were checked by using modified Folin-Ciocalteu method, colorimetric method, ferric reducing antioxidant power (FRAP) assay and high-performance liquid chromatography (HPLC) respectively. Significantly, highest TPC (1.852 ± 0.021 mg GAE/mL) was observed in Ceylon black tea sports drink while the highest TFC (1.252 ± 0.006 mg RE/mL), TAC (27.916 ± 0.121 mg TE/mL), epicatechin (1.07 mg/300 mL) and epigallocatechin gallate (8.29 mg/300 mL) contents were present in Ceylon green tea sports drink. According to the pH, titratable acidity (TA) and total soluble solid (TSS), higher acidity ranges and higher TSS contents were recorded by commercially available samples. Accordingly, the addition of tea demonstrated the enhancement of health benefits and thereby, the novel formulations can be concluded as healthy natural sports drinks.

Keywords: Antioxidant; Electrolytes; Phytochemicals; Sports drink; Tea

1. Introduction

Sports drinks are the beverages whose stated purpose is to help athletes replace water, electrolytes, and energy before and after sport or exercises. During strenuous exercises and sports, blood flow to the skin is increased to facilitate heat dissipation, and sweating implies loss of water and electrolytes from the body. Fluid loss results in decreasing circulatory blood volume and pressure followed by decrease in skin blood flow, all of which impair heat dissipation leading to the dehydration [1]. It is critical for the body to maintain the distribution of electrolytes to the maintenance of the transmembrane electrical and chemical gradients to assure the integrity of cell functioning and electrical communication throughout the body. So, in case of hyponatremia (low plasma sodium) due to excessive water intake which has occasionally been reported in sportsman, the symptoms include mental confusion, weakness and fainting caused and at extreme, coma and death may occur [2].

Current nutritional recommendations for the endurance athletes emphasize the drinking of electrolyte replenishing drink during exercise to prevent excessive dehydration and excessive changes in electrolyte balance. Normal human

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reference range of osmolality in plasma is about 275-299 milli-osmoles per kilogram [3]. So, the plasma osmolality should be regulated by controlling the water and the solute loss. Sports drinks provide the addition of electrolytes up to a rate equal to the compensation of the plasma osmolality to assist with intestinal absorption of water and muscle-glycogen replenishment and effective in omitting the dehydration risk while delaying the onset of fatigue by providing rapidly available energy [2].

Effectiveness of the electrolyte drink depends on the added sources. An appropriate source of carbohydrate such as maltodextrin generates energy with an optimum osmolality while maintaining a continuous energy density synergistically with glucose [4]. Generally, the addition of sodium and potassium sources with a carbohydrate to sports drinks is widely recommended to enhance water absorption which optimize the plasma osmolality while showing a higher rehydrating quality and the superficial stimulant action.

Although the consumption of sports drinks are essential, most of the commercially available sports drinks are formulated synthetically by incorporating chemicals that may cause health hazards and most of the people are reluctant to use them. Generally, caffeinated drinks are mostly considered as harmful to the health as at very high doses, caffeine can have negative affects ranging from sleep disturbance to anxiety to cardiovascular complications [5]. Therefore, an alternative to be introduced with healthier ingredients apart from chemicals that can be synthesized with natural stimulants and energy sources which shows a good rehydration ability during sporting. The excellent media known to be studied is tea. As a whole, tea responsible for developing a flavor that is consumed whole rather than brewed, making it convenient and incredibly nutrient dense compared to other tea and by blend it into a drink mix helps to keep the overall flavor profile light and prevents the overly tannic taste profile that was common when drinking tea.

This study was conducted to formulate two qualitative tea based carbohydrate electrolyte replenishing drinks by using Ceylon black tea and Ceylon green tea while assessing the appropriate compositions of the constituent to be added which matches the plasma osmolality of the drink with the human blood while achieving the best flavor and quality. In addition, total phenolic content (TPC), total flavonoid content (TFC), total antioxidant capacity (TAC), and contents of catechins, pH, total acidity (TA), total soluble solids (TSS) present in the end product was assessed to contrast health benefit of tea sport drinks. Finally, this study on developing a tea based sports drink can be considered as an initiative to the value added tea sector of Sri Lanka.

2. Material and methods

2.1. Location

This study was carried out at the Business Research and Development (BREAD) Center of National Enterprise Development Authority (NEDA) and the Laboratory of Department of Plantation Management, Wayamba University of Sri Lanka during the period from June to October, 2018.

2.2. Materials

The food grade electrolytes *i.e.* Sodium Chloride, Potassium Chloride, Magnesium Chloride, Tri Sodium Citrate and the carbohydrate sources *i.e.* Glucose, Maltodextrin with an organic acid *i.e.* Citric Acid used in the formula of sports drink were purchased from Glorchem Enterprise, Colombo 11. Ceylon black tea (Broken Orange Pekoe grade) was purchased from Waltrim Tea Factory, Lindula, Sri Lanka. Ceylon green tea (Gun Powder grade) was collected from Radella Tea Factory, Radella, Nuwaraeliya.

Mineral water was purchase from Nilsa (Pvt.) Ltd., Daraluwa, Sri Lanka. Commercially available sports drinks samples; SPD 1, SPD 2, SPD 3, SPD 4 were purchased from supermarket.

2.3. Method

2.3.1. Formulation of the initial electrolyte formula

The initial electrolyte formula (Table 1) was formulated by referring a standard formulation which matches the plasma osmolality. The osmolality of the initial formula was checked with the addition of carbohydrate and citric acid levels by using model 3320 Osmometer (Norwood, Massachusetts).

Table 1 The initial electrolyte formula

Reagent	g/L
Sodium Chloride	1.00
Potassium Chloride	0.20
Magnesium Chloride	0.09
Tri Sodium Citrate	0.15
Glucose	45.00
Maltodextrin	10.00
Citric Acid	0.13

2.3.2. Preparation of tea liquor

Addition of tea

Ceylon black tea liquor was prepared by brewing 10 g of Ceylon black tea in 100 mL of hot mineral water (80°C) for 10 min. Liquor of Ceylon green tea was prepared by brewing 10 g of tea in 200 mL of hot mineral water (80°C) for 10 min. Series of 10 mL, 15 mL, 20 mL and 25 mL of Ceylon black tea liquor and series of 5 mL, 10 mL and 15 mL of Ceylon green tea liquor were added separately to formulate black tea sports drinks (CeBSD) and Ceylon green tea sports drink (CeGSD), respectively while checking the osmolality.

2.3.3. Sensory evaluation

All four sports drinks (Table 2) which match to the plasma osmolality were taken for the consumer preference test to select the best proportion of Ceylon black and green tea to be added for the separate formulae of the tea based sports drinks. Taste, flavour, colour, mouth feel and overall acceptability were determined by 25 untrained consumers. After serving, consumers were asked to rate the given quality parameters according to the 5 point hedonic scale; 1- Dislike very much, 2- Dislike, 3- Neither like or Dislike, 4- Like, 5- Like very much. The highly preferred sample from each type of drink was selected by statistical analysis.

Table 2 Osmolality adjusted tea based sports drinks

Drink	Concentration of tea (%)	Osmolality (mOsm/Kg)
CeBSD 1	10	295.00
CeBSD 2	15	298.33
CeGSD 1	10	292.00
CeGSD 2	15	292.33

CeBSD-Ceylon black tea sports drink; CeGSD-Ceylon green tea sports drink

The same procedure was followed to conduct the second sensory evaluation on selected two drinks; CeBSD, CeGSD to compare with commercially available sport drinks in the local market.

2.3.4. Determination of bioactive compounds and antioxidant capacity

The total phenolic content (TPC) was quantified using a modified Folin-Ciocaltue method [6] and expressed in milligram of gallic acid equivalent (GAE). The total flavonoid content (TFC) of the samples were measured by a colorimetric method, with modifications [7] and expressed in milligram of Rutin equivalent (RE). Total antioxidant capacity (TAC) was determined using ferric ion reducing antioxidant power (FRAP) assay as described by Benzie and Strain [8] and expressed as miligram of trolox equivalent (TE). The content of catechins were determined by high-performance liquid chromatography (ISO 14502-2:2005) and expressed in milligram per 300 mL.

2.3.5. Determination of physicochemical properties

pH was tested by using digital pH meter (Gondo, Taiwan) at room temperature [9] and the titratable acidity (%) was determined using visual titrimetric method [10]. TSS was tested by using pocket refractometer (Atago, Japan) and expressed as Brix% [9].

2.3.6. Statistical analysis

Data on sensory evaluation were analyzed by non-parametric Kruskal Wallis Test followed by Mann Whitney Test and quantitative data were subjected to analysis of variance (ANOVA) procedure using SAS statistical software (SAS institute, 1999).

3. Results and discussion

3.1. Sensory evaluation

In sensory evaluation 1, there were significant differences ($p<0.05$) in all sensory attributes; taste, flavour, colour, mouth feel and overall acceptability of each couple of drink formulated by the addition of the same type of tea (Table 3). Tea drinks; CeBSD 1 (10% Ceylon black tea) and CeGSD 1 (10% Ceylon green tea) recorded the highest mean values for all the attributes. Therefore, two drinks were selected for the formulation of the natural tea based sports drinks.

Table 3 Results of the sensory evaluation 1

Drinks	Taste	Flavor	Color	Mouth Feel	Overall Acceptability
CeBSD 1	4.08	4.04	4.28	3.76	4.12
CeBSD 2	1.80	2.36	2.72	2.04	2.08
CeGSD 1	4.24	3.76	3.92	4.08	4.32
CeGSD 2	2.04	2.48	2.64	2.32	2.32

CeBSD 1- Ceylon black tea drink (10% Ceylon black tea); CeBSD 2- Ceylon black tea drink (15% Ceylon black tea); CeGSD 1- Ceylon green tea drink (10% Ceylon green tea); CeGSD 2- Ceylon green tea drink (15% Ceylon green tea).

In sensory evaluation 2, the highest acceptability was recorded by CeBSD and SPD 2 with significant differences ($p<0.05$) in all the attributes comparatively with other drinks (Table 4). The lowest acceptability was recorded by SPD 4 which was a commercially available sample. Basically, the acceptability was ranked by the consumers with the consideration of the artificiality with the additives. Therefore, the CeBSD ranked at the second best position while green tea sports drinks were ranked at higher positions. It was the best hint on demand when commercializing the natural tea based sports drink in the prevailing market on isotonic sports drinks.

Table 4 Results of the sensory evaluation 2

Sport Drinks	Taste	Flavor	Color	Mouth feel	Overall Acceptability
SPD 1	2.27	2.47	4.40	2.13	2.47
CeBSD	3.40	3.53	3.53	3.27	3.40
SPD 2	3.47	3.87	3.67	3.40	3.07
CeGSD	2.87	3.27	3.40	3.00	3.07
SPD 3	3.20	2.87	3.07	3.00	3.20
SPD 4	2.13	2.67	2.73	2.00	2.20

SPD - Commercially available sports drink; CeBSD - Ceylon black tea drink (10% Ceylon black tea); CeGSD - Ceylon green tea drink (10% Ceylon green tea).

3.2. Bioactive compounds and antioxidant capacity of sports drinks

TPC of tea based sports drinks and commercially available sport drinks were shown in Table 5. The results highlighted that the formulated natural products were rich in phenolic compounds and the TPC values for CeBSD and CeGSD were significantly higher than those of commercially available drinks due to the incorporation of tea. The highest TPC was

observed in CeBSD (1.85 ± 0.02 mg GAE/mL) whereas, the control which contained initial electrolyte formula without adding tea showed the least TPC (0.001 ± 0.001 mg GAE/mL). There were significant differences among TPCs of tea sport drinks due to the variations in formulation procedures which uses two different types of tea; Ceylon black tea and Ceylon green tea for different formulae. There was no any significant difference among TPCs of commercially available samples including the control.

Table 5 Total phenolic content (TPC), total flavonoid content (TFC) and total antioxidant capacity (TAC) of sports drinks

Drink	TPC (mg GAE/ mL)	TFC (mg RE/ mL)	TAC (mg TE/ mL)
CeBSD	1.852 ± 0.021[a]	1.245 ± 0.010[a]	20.397 ± 0.152[c]
CeGSD	1.636 ± 0.019[b]	1.252 ± 0.006[a]	27.916 ± 0.121[a]
SPD 1	0.011 ± 0.001[d]	0.151 ± 0.003[f]	0.055 ± 0.003[d]
SPD 2	0.002 ± 0.001[d]	0.225 ± 0.006[e]	0.020 ± 0.004[d]
SPD 3	0.028 ± 0.000[d]	0.270 ± 0.004[d]	0.035 ± 0.004[d]
SPD 4	0.028 ± 0.001[d]	0.293 ± 0.004[c]	0.059 ± 0.004[d]
Control (without adding tea)	0.001 ± 0.001[d]	0.135 ± 0.006[f]	Not detected

Means denoted by the same letters in a column represent non-significant differences ($p<0.05$);
RE- Rutin Equivalents; GAE- Gallic acid equivalents; TE- Trolox equivalents; SPD- Commercially available sports drink; CeBSD- Ceylon black tea drink (10% Ceylon black tea); CeGSD- Ceylon green tea drink (10% Ceylon green tea).

Related to the TFC, tea based sports drinks recorded significantly higher TFCs due to the addition of tea (Table 5). TFC of CeGSD (1.252 ± 0.006 mg RE/mL) and CeBSD (1.245 ± 0.010 mg RE/mL) were significantly higher than other drinks. However, there were no any significant difference between them. The lowest TFC (0.135 ± 0.006 mg RE/mL) was recorded by the control. According to the values of TFC, the catechin profile was enriched in Ceylon green tea drink compared to the other drinks.

Considering TACs, Green tea based sports drinks were highlighted due to the presence of tea catechins and other bioactive compounds (Table 5). The highest TAC was recorded by CeGSD (27.916 ± 0.121 mg TE/mL) and it shows a significant difference among other drinks. Similar to TPC and TFC, all the commercially available sports drinks recorded a significantly lower TAC. The TAC was not detected in control indicating the contribution of catechins in tea to the antioxidant capacity.

Table 6 Content of catechins in tea based sports drinks

Drinks	EC (mg/300 mL)	EGCG (mg/300 mL)
CeBSD	Trace	Trace
CeGSD	1.07[a]	8.29[a]

Means denoted by the same letters in a column represent non-significant differences ($p<0.05$); EC- Epicatechin; EGCG- Epigallocatechin gallate; CeBSD- Ceylon black tea drink; CeGSD- Ceylon green tea drink.

Catechin quantification demonstrated the availability of Epicatechin and Epigallocatechin gallate in novel formulations (Table 6) and a significant amount of Epicatechin (1.07 mg/300 mL) and Epigallocatechin gallate (8.29 mg/300 mL) was observed in CeGSD due to the preservation of catechin without decaying into theaflavins and thearubigins in green tea processing. Amount of catechins present in CeBSD shown to be nil due to the processing techniques of black tea.

3.3. Physicochemical properties of sports drinks

The highest pH was recorded by green tea sports drink; CeGSD (3.99 ± 0.03), while comparatively lower pH ranges were recorded by commercially available samples (Table 7). The control recorded the pH of 3.55 ± 0.02 which was due to the action of electrolytes and the presence of citric acid in the initial electrolyte formula (Table 1) which was added to increase the palatability by making a little sour taste.

Table 7 Total soluble solids (TSS), pH and titratable acidity (TA) of sports drinks

Drink	TSS (Brix %)	pH	TA (%)
CeBSD	5.67 ± 0.06^{c}	3.87 ± 0.02^{b}	0.10 ± 0.00^{bc}
CeGSD	5.27 ± 0.06^{d}	3.99 ± 0.03^{a}	0.06 ± 0.00^{c}
SPD 1	7.67 ± 0.12^{b}	2.35 ± 0.01^{d}	0.32 ± 0.06^{a}
SPD 2	3.23 ± 0.06^{g}	2.29 ± 0.01^{e}	0.19 ± 0.06^{abc}
SPD 3	7.77 ± 0.15^{b}	2.35 ± 0.01^{d}	0.19 ± 0.00^{abc}
SPD 4	8.20 ± 0.20^{a}	2.36 ± 0.01^{d}	0.23 ± 0.04^{ab}
Control (without adding tea)	3.80 ± 0.17^{f}	3.55 ± 0.02^{c}	0.23 ± 0.10^{ab}

Means denoted by the same letters in a column represent non-significant differences ($p<0.05$); TSS- Total Soluble Solids; TA- Titratable Acidity; SPD- Commercially available sports drink; CeBSD- Ceylon black tea drink (10% Ceylon black tea); CeGSD- Ceylon green tea drink (10% Ceylon green tea).

The highest TA was recorded by SPD 1 (0.32 ± 0.06%) and the lowest TA was recorded by green tea sports drink; CeGSD (0.06 ± 0.00%) (Table 7). It demonstrated the absence of artificial acidic components and additives. Other commercially available drinks were recorded comparatively higher percentage of acidity. The highest TSS was observed in SPD 4 (8.20 ± 0.20% brix) whereas the lowest TSS was recorded by the control (3.80 ± 0.17% brix). Among the tea based sports drinks, CeBSD (5.67 ± 0.06% brix) recorded the highest TSS but, it was lower than that of commercially available drinks. It emphasized the health benefits of the tea sports drinks as higher acidic and TSS values created by sucrose can negatively affect upon energy density, sleep, skin and oral health and memory.

Effectiveness of the sports drink depends on the added sources. The incorporated black tea and green tea in the formulation of sports drinks accounts for the antioxidant action. In view of sports, tea components; catechins (10-18%), caffeine (3-4%), theanine (1-2%) have the potential to affect the absorption and metabolism of ions [11], reduction of age related decline in endurance performance, helps in preventing muscle wasting while acting as a stimulant, mood stabilizer, improving focus, performance enhancing, improve alertness, enhancing glycogen re-synthesis [12]. An appropriate source of carbohydrate; maltodextrin generates energy with an optimum osmolality while maintaining a continuous energy density synergistically with glucose [4].

4. Conclusion

The novel formulation of the natural sports drinks with Ceylon black tea and Ceylon green tea were developed.

Health benefit was highlighted in the natural formulations with natural flavours, colours. As sports drinks, it bears an excellent rehydration ability with an optimum electrolyte balance along with an optimum continuation of energy density by maltodextrin which supports the sportsman during sports. It provides the addition of electrolytes and carbohydrates to assist with intestinal absorption of water and muscle-glycogen replenishment, respectively. As well as, Gastric Emptying is proportionally slowed by rehydration drinks with carbohydrates results in a relatively constant stomach volume maintained by gastric secretion and by emptying into the small intestine.

Compliance with ethical standards

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Disclosure of conflict of interest

All the authors certified that they have NO any affiliations with any organization or entity with any financial interest or non-financial interest in the subject materials discussed in this manuscript.

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