Utilization of hibiscus, tamarind and carob in production of low calories healthy soft drinks

ABSTRACT

The demand for carbonated beverages is increasing, offering opportunities to develop drinks with significant health benefits. Beverages containing carob, tamarind and hibiscus offer multiple nutritional and functional benefits and can serve as healthy alternatives to other soft drinks on the market. This is particularly important given the high sugar and calorie content of traditional soft drinks, which has been linked to increased issues associated with obesity, type 2 diabetes, osteoporosis and cardiovascular disease globally. The focus of the current work is to evaluate low-calorie soft drinks made from hibiscus, tamarind and carob and sweetened with erythritol that cater to diverse consumer segments, including diabetics and health-conscious individuals. Hibiscus, tamarind and carob extracts were sweetened with 0.5, 1 and 1.5 g erythritol sugar/200 ml carbonated beverage.The results showed that the alcoholic extract from hibiscus cups gave the highest content of phenols and flavonoids (70.3 mg gallic/g on DW and 7.8 mg catechin/g on DW), followed by carob pod alcoholic extract (19.3 mg gallic/g on DW) and tamarind alcoholic extract (11.6 mg gallic/g on DW). Tamarind gave a higher content of flavonoids (2.3 mg/g) than carob (1.2 mg/g); however, carob pods had the highest antioxidant activity (91.92%), followed by tamarind pulp (87.66%) and hibiscus cups (79.76%). The soft drinks of hibiscus and tamarind sweetened with erythritol at 1.5 g/200 ml gave the best sensory properties compared with control (adjusted by sucrose at 12% brix) and others concentrations used of erythritol sugar at (0.5 and 1.5 g /200 ml carbonated beverage). Carob pods soft drink sweetened with 0.5 g erythritol /200 ml gave the best sensory characteristics compared to the control sample and others concentrations of erythritol sugar at (1 and 1.5 g /200 ml carbonated beverage), which may be due to the high content of sugars in carob.Hibiscus carbonated beverage outperformed tamarind in terms of overall acceptability and carob carbonated beverage was the least acceptable in terms of sensory properties. Carob carbonated beverage recorded the highest antioxidant activity (90.9%) and phenolic content while representing the second highest in terms of flavonoids. Tamarind carbonated beverage ranked second in terms of antioxidant activity (86.0%) and phenolic content although it ranked first in terms of flavonoids. Hibiscus carbonated beverage recorded the lowest content in terms of antioxidant activity (79.36%), phenolic compounds and flavonoids. Hibiscus, tamarind and carob are a great choice for the production of carbonated beverages because they give the beverage desirable nutritional, cosmetic and medicinal qualities. Moreover, the simplicity of production and availability of raw materials allows for the stimulation of the economy by reducing dependence on multinational companies offering unhealthy orindustrialized soft drinks.

Keywords: Carbonated beverages, carob pods, hibiscus, tamarind.

1. INTRODUCTION

The food and beverage industry is one of the largest globally, with soft drinks emerging as a dominant force in the market. Soft drinks are defined by their dissolved carbon dioxide content, which creates distinctive bubbles, or effervescence, when released and enhances the visual appeal of carbonated water as well as their palatability.The carbonation process involves passing pressurized carbon dioxide through water to form carbonated water. The increased pressure enhances the solubility of carbon dioxide. These beverages are produced by pumping carbon dioxide into the liquid before bottling. At a temperature of 298 K, carbon dioxide has a density of 1.98 kg m3, making it denser than air [1]. Carbonation has grown in popularity due to its ability to impart a delicious flavor. According to [2], carbonation is responsible for the refreshing sensation and enhanced flavor found in carbonated products.Soft drinks are one of the most commonly used forms of sweetened beverages. Soft drinks are non-alcoholic, sweet, lightly flavored beverages that contain carbon dioxide to provide a fizzy effect. The flavor compounds used may be artificial or natural, and are usually colored and canned with fruit pulp or juice. Sweeteners may include fruit juice, fructose corn syrup, sugar, or sugar substitutes. Soft drinks consist of 90% to 98% water, 8-12% sugar, 0.1-0.5% flavorings, 0.3-0.6% carbon dioxide, 0.05-0.3% acidic ingredients, and 0-70 ppm colors with preservatives according to regulations. To maintain safety and stability, emulsifiers of 01-0.2% are used to preserve fruit juices up to 10%, reducing the amount of sugar needed. Other ingredients (saponins, antioxidants, etc.). Saponins are used to stabilize the foam and antioxidants prevent ingredients from oxidizing during storage. Carbon dioxide (CO_2) is a colorless, odorless, tasteless, inactive, non-toxic gas in nature that, when dissolved in water, produces carbonic acid. The highest concentration of CO_2 that can be dissolved in water is 8 grams per liter. Carbon dioxide has a preservative function by inhibiting the growth of microbes such as yeast, mold, and lactic acid bacteria. It also protects the cans from deformation [3].

In 2014, the World Health Organization [4]revised the 2002 rule to restrict free sugar intake to the equivalent of 25 grams per day for women and 35 grams per day for men to match a normal diet of 1,900 and 2,600 calories, respectively [5]. Consumption of more than 5 servings (one serving 334 ml) of any type of beverage per week has been linked to a higher risk of metabolic syndrome and its components. Individuals who consumed 1-2 cups of soft drinks per day were 26% more likely to develop type 2 diabetes than those who did not consume [6].Excessive soft drink consumption, particularly refined sugars like fructose, is linked to cardiovascular disease, arterial hypertension, and dysregulation, posing a significant public health concern[7].In addition, it raises blood pressure, triglycerides, visceral fat, insulin resistance, and HDL cholesterol levels, all of which are linked to an increased risk of cardiovascular disease[8]. A 4-year follow-up research revealed that healthy American women who consumed sweetened beverages gained significantly more weight than women who consumed no sweetened beverages or only artificially sweetened beverages [9]. According to a different recent meta-analysis, consuming 334 milliliters of sugary drinks per day was associated with a higher risk of diabetes [10]. Studies have shown that consumption of sugar-sweetened beverages, including cola, is associated with lower bone mineral density, which increases the risk of osteoporosis. The caffeine and phosphoric acid in cola raises the level of calcium in the urine [9].Erythritol is a sugar alcohol with 60-70% sucrose sweetness and no calories, used as a sweetener in drinks due to its low glycemic index. It is suitable for diabetics due to its glycemic benefits and compatibility with a diabetic diet. However, excessive use can cause bloating and gastrointestinal issues. Polyols like erythritol do not require insulin for metabolism[11].The demand for soft drinks grows by the day, opening up new prospects for beverages to provide considerable therapeutic, health, and nutritional advantages. According to a research by [12], the functional beverage business is rapidly expanding, making it one of the market's fastest growing sectors. Manufacturers are increasingly working on generating innovative goods with increased nutritional value and sensory appeal to fulfill their consumers' expectations. Beverages prepared from medicinal plants are becoming increasingly popular among consumers due to their health advantages and high antioxidant content, which includes flavonoids, phenolics, and anthocyanins, making them good alternatives [13].Hibiscus, carob, and tamarind are plants that provide great health benefits. They contain many bioactive compounds such as flavonoids, polyphenols, and anthocyanins, which can protect against oxidative stress. This protection helps prevent certain chronic diseases such as atherosclerosis, diabetes, and cancer. H. sabdariffa extracts prevented LDL oxidation in vitro and lowered blood cholesterol levels in cholesterol-fed mice and rabbits [14]. The utilization of medicinal plants in the creation of therapeutic food products has gained popularity as more individuals prioritize healthy living. Consequently, there is an increasing demand for nutritional drinks such as hibiscus, carob, and tamarind, which contain an ample amount of bioactive compounds to help in the prevention or treatment of certain human diseases [15].Research shows that natural hibiscus extract has antioxidant properties and can help prevent hypertension, diabetes, cardiovascular disease, and liver damage [16]. Consuming hibiscus drinks can improve metabolism and prevent obesity. Consuming one cup of hibiscus drink twice a day, containing 250 mg of anthocyanins, is recommended for controlling high blood pressure [17]. Anthocyanins protect the body from oxidative stress and stimulate nitric oxide production, leading to vasodilation [18]. Consuming anthocyanin-rich foods also improves lipid profile and platelet function [19]. Red dry hibiscus cups were found to have a chemical composition of 11 moisture, 0.16% fat, 13.2% fiber, 7.88% protein, 10.6% ash, and 57.16% carbohydrates, along with 11 mg/100g vitamin C, 60 mg/100g calcium, 25 mg/100g iron, and 9 mg/100g titratable total acidity [20].

The carob fruit is known for its effectiveness in preventing chronic diseases and providing significant health benefits such as lowering cholesterol, fighting cancer, regulating blood sugar, and acting as an antimicrobial agent [21]. This is due to its richness in dietary fiber, polyphenols, flavonoids, and condensed tannins, which contribute to its high antioxidant capacity [22].The aqueous extract of carob seeds has demonstrated potent antioxidant activity by effectively inhibiting the formation of free radicals such as 2,2-diphenyl-1-picrylhydrazyl, hydroxyl, and nitric oxide. Additionally, it has shown strong inhibitory effects against digestive enzymes, including amylase, maltase, saccharase, and lactase. Furthermore, the extract has exhibited antimicrobial properties against a variety of microbes and has proven effective in safeguarding the red blood cell membrane from hemolysis caused by a hypotonic solution. These findings underscore the value of carob pod extract as a source of antioxidants, with potential antidiabetic properties, and support its potential applications in pharmaceuticals and food supplements [23].[24] found that the proximate chemical composition of carob pods was 7.53% moisture, 5.42% protein, 54.36%

total sugars, 2.72% ash, 1.94% fat, 6.81% crude fiber, while the mineral content as mg/100g was 15. 88 magnesium, 152.0 sodium, 0.94 zinc, 1.66 manganese, 2.38 iron, 488.6 calcium and 135.4 potassium, total phenolic compounds were 21.07 mg/100g and total antioxidant activity was 90.09%.

Tamarind contains pulp, seeds, peel, and fiber. The pulp makes about 30-50% of the ripe fruit and is high in reducing sugars, pectin, protein, fiber, and cellulose. Tamarind is also strong in important amino acids and phytochemicals, which contribute to its anti-diabetic, antibacterial, and antioxidant effects [25]. The fruits have a 38% moisture content [26]. It is abundant in minerals (calcium, phosphorus, copper, and manganese) and has the most B vitamins. Tartaric acid concentrations vary from 8 to 18%, reducing sugars from 25 to 45%, pectin 2-3.5%, and protein 2-3% [27]. It also includes pyranines, thiazoles, alkaloids, flavonoids, saponins, and tannins. The pulp is thought to have lipid-lowering, antioxidant, antifluoride, analgesic, hepatoprotective, and antispasmodic effects [28].

Tamarind extract has antibacterial, antipyretic, diuretic, carminative, humectant and hemorrhoid tonic properties. It also has anti-worm, intestinal relaxant, stomach upset, jaundice, eye disorders, ulcers and conjunctivitis properties [29]. It is considered an aphrodisiac, sperm tonic and reproductive safe [30]. It has benefits in treating colon cancer and protection against lipid peroxidation [31].Hibiscus, tamarind, and carob drinks are popular due to their medicinal benefits and low cost compared to other soft drinks, most of which come from foreign companies and drain the economy. The global demand for functional food products is increasing, prompting the food industry to meet the needs of consumers who are looking for nutritious, convenient, delicious and attractive foods [32]. Understanding the physicochemical properties of food products is of paramount importance as they directly influence consumer responses [33]. This study aims to develop low-calorie soft drinks from hibiscus, tamarind and carob, and evaluate their sensory and chemical properties.

2. MATERIALS AND METHODS

2.1. Materials:

Red hibiscus (*Hibiscus sabdariffa* L.), carob pods (*Ceratonia siliqua* L.) and tamarind (*Tamarindus indica* L.) were obtained from local markets in Cairo Governorate.

2.2. Methods

2.2.1. Preparation of Beverages

Hibiscus and tamarind fruits were soaked overnight in distilled water (1:10 w/v), while carob pods were ground before soaking in distilled water in the same ratio as before, then boiled for 3 minutes and filtered with a muslin cloth to produce clear extracts. Erythritol was added to each beverage by 0.5 – 1 – 1.5 g/ 200 ml, cooled to 4℃, carbonated, then, the carbonated beverages were examined by panelists for sensory evaluation and the different analysis were done. Table 1 shows the different treatments and the percentages of sugar added to them.

Table 1:Different percentages of sugar alcoholadded to different drinks

Hibiscus	H 12	Control (adjust beverages concentration at 12 brix by sucrose sugar)
	H 0.5	Addition erythritol to beverage by 0.5 g/ 200 ml
	H 1	Addition erythritol to beverage by 1 g/ 200 ml
	H 1.5	Addition erythritol to beverage by 1.5 g/ 200 ml
Tamarind	T12	Control (adjust beverages concentration at 12 brix by sucrose sugar)
	T 0.5	Addition erythritol to beverage by 0.5 g/ 200 ml
	T1	Addition erythritol to beverage by 1 g/ 200 ml
	T 1.5	Addition erythritol to beverage by 1.5 g/ 200 ml
Carob	C12	Control (adjust beverages concentration at 12 brix by sucrose sugar)
	C 0.5	Addition erythritol to beverage by 0.5 g/ 200 ml
	C1	Addition erythritol to beverage by 1 g/ 200 ml
	C 1.5	Addition erythritol to beverage by 1.5 g/ 200 ml

2.2.2. Analytical Methods

2.2.2.1. Physical and Chemical Analysis

TSS, pH value, titratable acidity, and ash content were determined using the [34] method. [35] recommended measuring the color index (absorbance at 420 nm). TPC was assessed using the Folin-Ciocalteu assay, using the procedure described by [36]. The findings were given in mg of gallic acid. To determine the amount of flavonoids, the technique of [37]was utilized. The results were represented in mg of catechin. The antioxidant activity was measured using the technique published by [38].

2.2.2.2. HPLC Analysis of Phenolic Compounds

HPLC was used to quantify polyphenolic fractions, following [39] technique. Following sample preparation, the liquid was fed into the HPLC Hewllet packed instrument (Series 1050), which was outfitted with an autosampler, solvent remover, ultraviolet (UV) detector set to 280 nm, and HP quarter pump. The column's temperature remained at 35°C. The quantitative identification of phenolic substances is done at 280 nm using several standards. The retention duration and peak area (%) were used to calculate the quantity of phenolic compounds using a Hewlett-Packard data system.

2.2.2.3. HPLC analysis of Flavonoids

HPLC was used to measure flavonoid components subsequent[39] approach. Following sample preparation, the sample was injected into a packed HPLC Hewllet (Series 1050) that included an auto-sampling injector, solvent remover, 330 nm ultraviolet (UV) detector, and HP quarter pump. The column was maintained at 35 °C, and flavonoids were quantified at 330 nm wavelength using several standards. The retention duration and peak area (%) were used to calculate flavonoid concentrations using a Hewlett-Packard data system.

2.2.2.4. Color Measurement

Spectral reflectance was quantified using a spectrophotometer. Color was assessed through the measurement of the L*, a*, and b* components, which correspond to lightness, green-red, and blue-yellow, respectively [40]. Color**2.2.2.5. Sensory Analysis**

Ten novice panelists utilized a 9-point hedonic scale to evaluate carbonated drinks based on taste, odor, color, mouthfeel, and appearance [41]. The assessment involved five samples, and the overall acceptability was determined based on the average ratings of the test attributes.

2.2.2.6. Statistical Analysis

The results were subjected to a statistical analysis of variance (ANOVA) using the procedure outlined by the Statistical Analysis System (SAS) program, as described by [42]. Significant differences were identified at the level of $P \leq 0.05$.

3.RESULTS AND DISCUSSION

Table 2. Chemical composition of rosella, tamarind and carb pods

	Hibiscus	Tamarind	Carb pods
Moisture (g/100g)	13.2	23.56	9.8
Protein (g/100g)	8.9	4.6	6.2
Fat (g/100g)	0.62	5.8	1.1
Fiber (g/100g)	11.63	11.2	19
Ash (g/100g)	11.22	3.22	3.3
Carbohydrates (g/100g)	54.43	51.62	60.6
pH	2.89	3.48	5.71
Acidity%	16.2	11.6	0.9
V.C mg/100g	70.1	12.2	2.4
color index	0.126	0.250	0.111
Total phenolic compounds (mg GAE/g DW)	70.3	11.6	19.3
Total flavonoid content (mgCE/g DW)	7.8	2.3	1.2
anthocyanin mg/g	23		
Antioxidantsactivity%	79.76	87.66	91.92
Mg (mg/100g)	266.3	52	18.3
Na (mg/100g)	8.5	73	132
K (mg/100g)	188	325	144
Mn (mg/100g)	55	1.67	2.9
Fe (mg/100g)	3.3	8.54	4.1
Ca (mg/100g)	616	334	302
Zn (mg/100g)	13.2	1.3	0.8
P(mg/100g)	22	104	72

Table 2 shows the compositional characteristics of hibiscus, tamarind and carob pods. Carob pods contain high concentrations of carbohydrates, fiber, antioxidants, and sodium with high pH (60.6 g/100 g, 19 g/100 g, 91.92%, 132 mg/100 g, and 5.71) compared to hibiscus and tamarind. Tamarind recorded the highest moisture content, fat content, color index, potassium, iron and phosphorus content (23.56%, 5.8 g/100g, 0.25, 325 mg/100g, 8.54 mg/100g and 104 mg/100g). The highest levels of protein, ash, acidity, phenolic content, flavonoids content, magnesium, manganese, calcium and zinc (8.9%, 11.22%, 16.2%, 70.3 mg/g, 7.8 mg/g, 266.3 mg/100 g, 55 mg/100 g, 616 mg/100 g and 13.2 mg/100 g were recorded by hibiscus. These findings are consistent with research conducted by [43-44].Rosella is a potential functional food, high in anthocyanins (23 mg/g), phenolic acids and flavonoids (70.3 and 7.8 mg/g) Which is characterized by its high content of antioxidants.The results are consistent with [45] which found that the anthocyanin content in hibiscus cups is up to 25 mg/g on a dry weight basis. Roselle cups are rather acidic (16%) and contain more ascorbic acid than oranges and mangoes, as indicated [46]. It is also contains antioxidants such as flavonoids [47].Carob pulp has recently deserved special attention due to its aforementioned high content of polyphenols and tannins, which have been recognized as antioxidants and root scavengers with potential health-promoting effects [48]. Carob pulp is abundant in bioactive compounds, particularly polyphenols. Both carob and its ethanol extract demonstrate a robust antioxidant activity (91.92%), effectively inhibiting DPPH. This antioxidant activity is attributed to the active ingredients in carob pods, which can donate hydrogen to free radicals, neutralizing the electron responsible for radical reactions. These findings are consistent with studies by [49-50-23].Although carob is high in carbohydrates (60.6%), it has a significant anti-diabetic effect, giving carob great importance as a natural sweetener for diabetics. This is due to its strong inhibitory effect against all digestive enzymes such as alpha-amylase and alpha-glucosidase[51]. Numerous investigations have demonstrated that polyphenols, notably phenolic acids, flavonoids, and tannins, have a significant effect in hindering alpha-glucosidase and alpha-amylase, two vital enzymes that facilitate the conversion of carbohydrates into glucose[52].

Table 3. Phenolic and flavonoids compounds of methanolic extracts of hibiscus, tamarind and carb pods

	Phenolic compounds µg/100g				Flavonoids µg/100g		
	Hibiscus	**Tamarind**	**Carob**		**Hibiscus**	**Tamarind**	**Carob**
Pyrogallol	**4050.35**	**880.89**	**1462.77**	**Rutin**	**8.44**	**11.51**	**11.09**
Gallic	**148.27**	**30.41**	**164.43**	**Naringin**	**42.16**	**33.96**	**21.53**
Catechol	**693.68**	**59.85**	**188.15**	**Rosmarinic**	**2.87**	**4.35**	**5.08**
4-Amino-benzoic	**523.28**	**41.23**	**9.7**	**Quercetrin**	**12.26**	**18.84**	**11.06**
Catechein	**700.63**	**56.27**	**137.77**	**Quercetin**	**15.68**	**24.66**	**9.76**
Chlorogenic	**154.17**	**8.7**	**32.74**	**Naringenin**	**2.93**	**20.11**	**6.45**
P-OH- benzoic	**13.04**	**1.73**	**1.08**	**Kampferol**	**8.18**	**13.43**	**11.21**
Benzoic	**164.03**	**0**	**9.64**	**Apigenin**	**3.72**	**14.44**	**8.3**
Caffeic	**151.81**	**0**	**6.54**	**leotuline**	**40.65**	**778.9**	**525.91**
Vanillic	**60.27**	**2.34**	**9.15**	**hesperdin**	**4049.86**	**2942.15**	**2904.94**
Caffeine	**0**	**0**	**0**				
Ferulic	**0.85**	**1.48**	**6.19**				
Ellagic	**1.89**	**1.91**	**4.89**				
Evanillic	**0.19**	**0.67**	**2.78**				
Salycilic	**0.04**	**0.8**	**3.65**				
Coumarin	**0.09**	**0.76**	**6.77**				
Cinnamic	**2.22**	**15**	**196.1**				

In recent years, attention has focused on the antioxidant properties of plant-derived food ingredients. Flavonoids and phenols have many biological and pharmacological properties that can offer safeguards against chronic illnesses. These substances stop all of the oxidation processes by donating a hydrogen atom or chelating metals which show stronger antioxidant activities [53]. Moreover, their bioactivities may be related to their ability to inhibit lipoxygenase enzymes and scavenge free radicals [54]. As shown in Table 3 rosella extract has a greater total phenolic concentration than carob, which follows tamarind. Several studies have shown that hibiscus extracts are abundant in polyphenols, bioactive compounds consisting of aromatic rings attached to one or more hydroxyl groups [55], many of which act as antioxidants. The most important phenolic compounds found in hibiscus (pyrogallol, catechein, catechol, 4-amino-benzoic, benzoic, chlorogenic, caffeic and gallic) while in tamarind (pyrogallol, catechol, catechein, 4-amino-benzoic, gallic and chlorogenic).High performance liquid chromatography (HPLC) analysis revealed that carob pod aqueous extract (CPAE) contained high levels of (pyrogallol, catechol, gallic, catechein, chlorogenic).Several studies have demonstrated that these molecules are known for their antioxidant and anticancer properties [56-57]. There are many data on carob components performed by HPLC, [22] found that the main components of carob are pyrogallol 48.0%, catechin 19.1%, and gallic acid present in a small amount of 3.1%. Polyphenols are very important phytochemicals that have been suggested to play a role in improving human health and preventing various diseases, including cancer [58], cardiovascular disease [59], oxidative stress [60], and exhibiting neuroprotective properties [61].

Hibiscus had the most flavonoids, followed by tamarind and carob. The most important flavonoids found in hibiscus were (hesperdin, naringin, leotuline, quercetin and quercetrin) while in tamarind (hesperdin, leotuline, naringin, quercetin and naringenin) and carob (hesperdin, leotuline, naringin, kampferol, rutin and quercetrin). These results are consistent with [45].

Table4. Sensory attributes of carbonated rosella, tamarind, and carob pods beverages

		Color	Taste	Flavor	Mouth feel	Texture	Overall acceptability
Hibiscus	**H 12**	8.0^{b}	8.0^{b}	7.7^{b}	7.3^{b}	7.5^{a}	7.7^{b}
	H 0.5	8.5^{a}	7.5^{c}	7.5^{c}	6.5^{c}	7.1^{b}	7.4^{c}
	H1	8.5^{a}	8.0^{b}	7.8^{b}	7.2^{b}	7.4^{a}	7.8^{b}
	H 1.5	8.5^{a}	8.5^{a}	8.1^{a}	7.9^{a}	7.5^{a}	8.1^{a}

Tamarind	**T12**	**6.6^{c}**	**6.1^{c}**	**6.6^{b}**	**7.0^{b}**	**4.8^{b}**	**6.2^{b}**
	T 0.5	**7.2^{b}**	**6.1^{c}**	**5.5^{c}**	**6.1^{d}**	**4.5^{c}**	**5.9^{c}**
	T1	**7.2^{b}**	**6.5^{b}**	**6.5^{b}**	**6.5^{c}**	**5.0^{b}**	**6.3^{b}**
	T 1.5	**8.2^{a}**	**8.5^{a}**	**8.1^{a}**	**7.5^{a}**	**6.3^{a}**	**7.7^{a}**
Carob	**C12**	**6.5^{c}**	**5.5^{c}**	**5.0^{c}**	**5.5^{d}**	**8.3^{a}**	**6.2^{c}**
	C 0.5	**8.0^{a}**	**6.8^{a}**	**7.5^{a}**	**7.1^{a}**	**6.4^{c}**	**7.2^{a}**
	C1	**7.8^{a}**	**6.4^{b}**	**6.8^{b}**	**6.4^{b}**	**6.5^{c}**	**6.8^{b}**
	C 1.5	**7.1^{b}**	**4.5^{d}**	**4.5^{d}**	**5.9^{c}**	**7.6^{b}**	**5.9^{d}**

Table 4 shows the organoleptic characteristics of the carbonated beverages produced from hibiscus, tamarind and carob. For hibiscus, the carbonated beverages sweetened with erythritol sugar at 1.5 g/200 ml gave the best sensory characteristics in terms of color, taste, flavor, mouthfeel, and texture compared to control which sweetned by sucrose until 12 brix and the rest treatments at 0.5 and 1 g erythritol /200 ml of the. This treatment was followed in terms of preference by the treatments sweetened with erythritol sugar alcohol at 0.5 and 1 g erythritol and then the control treatment. Color is the most important quality attribute that affects consumer acceptance of food because it gives the first impression of food quality [3]. The red color is due to the presence of anthocyanins in hibiscus. The use of low-calorie sweeteners increases the stability of anthocyanins in hibiscus. The same results are obtained by [62-63-46-47]. For tamarind carbonated beverages, T 1.5 was the best, followed by T1, T12 and T0.5. The C0.5 treatment of carob carbonated beverage recorded the best sensory properties despite the low concentration of erythritol used, which may be due to the high content of sugars in carob. The hibiscus drink outperformed the tamarind in terms of overall acceptance and the carbonated carob drink was the least acceptable in terms of sensory properties.The hibiscus plant is a great choice for the production of soft drinks because it gives the drink desirable nutritional, phenotypic and medicinal qualities and this information is supported by a study conducted by [63].The reason for the lower sensory properties of carob soft drink compared to hibiscus and tamarind may be due to the high content of tannins in carob pods, which is characterized by a bitter and astringent taste, which generally affects the consumer's palatability and this was supported by studies conducted by [64].

Table5. Physicochemical and antioxidants properties of carbonated rosella, tamarind, and carob pods beverages

	Carbonated beverages		
	Hibiscus 1.5	**Tamarind1.5**	**Carob0.5**
brix	**7**	**5.9**	**6.8**
pH	**2.6**	**3.57**	**5.83**
Acidity%	**1.85**	**1.22**	**0.2**
V.C mg/100ml	**55**	**70**	**0.4**
color index	**0.31**	**0.33**	**0.21**
Total phenolic mg/100ml as Gallic	**118.3**	**128.2**	**140.6**
Total flavonoid mg/100ml as catechin	**122.6**	**173.9**	**158.2**
anthocyanin mg/100ml	**536**		
Antioxidants%	**79.3**	**86.0**	**90.9**
Mg (mg/100ml)	**24.2**	**4.7**	**1.7**
Na (mg/100ml)	**0.8**	**6.6**	**12.0**
K (mg/100ml)	**17.1**	**29.5**	**13.1**
Mn (mg/100ml)	**5.0**	**0.2**	**0.3**
Fe (mg/100ml)	**0.3**	**0.8**	**0.4**
Ca (mg/100ml)	**56.0**	**30.4**	**27.5**
Zn (mg/100ml)	**1.2**	**0.1**	**0.1**
P(mg/100ml)	**2.0**	**9.5**	**6.5**

Table 5 shows the chemical composition of the resulting soft drinks from (hibiscus, carob, and tamarind). The low pH values in the hibiscus and tamarind soft drink samples (2.6 and 3.57) may be attributed to the presence of naturally occurring organic acids such as malic, citric, folic and oxalic acids, with acidity values of (1.85% and 1.22). Fumaric acid was found to be the most abundant in *Hibiscus sabdariffa* extracts [65]. Rosella drinks include numerous organic acids such as citric, malic, oxalic, and fumaric, which have antioxidant properties [66].The levels found are expected to restrict microbial development[67]. The high titratable acidity may be due to the activity of polymerase enzymes, responsible for the complex bacterial hydrolysis of polysaccharides, leading to an increased release of latent organic acids such as citric, malic, and ascorbic acid. The results indicate that hibiscus drink is naturally acidic, with a low pH between 2.57 and 3.87. This feature extends its shelf life by limiting the development of microorganisms. Furthermore, the experiment indicated that carbonation enhances total acidity of the drink by boosting carbonic acid levels in the system [68].The low levels of vitamin C content in the samples may be a result of oxidation caused by the utilization of amino acids, lipids and collagen synthesis. The same trend of results were pointed by [46].The carbonization process helped maintain the acidity of the drink, resulting in an increase in vitamin C content [68]. A product's degree of antioxidant activity is directly correlated with the overall amount of phenolic chemicals it contains. The phenolic contents of hibiscus, carob and tamarind soft drinks are 118.3, 128.2 and 140.6 mg/100ml as gallic acid and flavonoids (122.6, 173.9 and 158.2 mg/100ml as catechin). Phenolic compounds and flavonoids possess properties that enable them to act as antioxidants [69].Hibiscus is considered one of the drinks high in anthocyanin content, which is considered a phenolic substance with health, nutritional, and antioxidant benefits, Anthocyanin levels in hibiscus soft drinks reached 536 mg/100 ml, meeting the body's daily demands, which varies from country to country. The daily intake of anthocyanins is estimated at 82 mg and 12.5 mg per day per person in Finland and the United States [70].

Oxidative stress arises from an imbalance between the accumulation of excess free radicals in the body, capable of causing damage to a wide range of biological macromolecules such as lipids, proteins, and nucleic acids. However, having enough antioxidants in the body's system protects it from various harmful effects that may result from free radicals, pollutants, and toxins [71].The DPPH radical scavenging assay is a dynamic analytical technique developed to evaluate the antioxidant potential of biological materials. The highest antioxidant activity (90.9%) was recorded for carob carbonated beverage, followed by tamarind carbonated beverage (86.0%) and hibiscus carbonated beverage (79.36%). The observed effect can be attributed to the ability of phenolic compounds to scavenge free radicals [32]. The overall antioxidant activity of hibiscus extracts is the result of the combined contribution of phenolic compounds and organic acids [66]. The antioxidant activity was found to be significantly correlated with the total soluble polyphenol content and acidity, which increases as the concentration of hibiscus in beverages increases. The aromatic, astringent and sour properties of hibiscus beverages can be attributed to the phenolic compounds and organic acids present [72]. Moreover, anthocyanins not only contribute to the intense red color of hibiscus drinks, but also play an important role in their antioxidant capacity [32].Hibiscus, tamarind and carob soft drinks have a significant mineral content. Hibiscus soft drink is the highest in magnesium, manganese and calcium (24.2, 5 and 56.0 mg/100 ml) while tamarind soft drink recorded the highest content of potassium, iron and phosphorus (29.5, 0.8 and 9.5 mg/100 ml) while carob soft drink recorded the highest content of sodium (12 mg/100ml).

Table 6. Phenolic and flavonoids compounds of carbonated rosella, tamarind, and carob pods beverages

	Carbonated beverages						
	Phenolic compounds µg/100g				**Flavonoids µg/100g**		
	Hibiscus 1.5	**Tamarind1.5**	**Carob0.5**		**Hibiscus 1.5**	**Tamarind1.5**	**Carob0.5**
Pyrogallol	321.92	216.1	521.82	**Rutin**	0.27	5.24	1.37
Gallic	20.92	10.07	60.98	**Naringin**	11.41	21.56	5.06
Catechol	95.79	117.89	56.2	**Rosmarinic**	0.09	1.05	2.84
4-Amino-benzoic	9.36	7.74	7.73	**Quercetrin**	0.15	7.19	2.49
Catechein	73.21	235.79	87.86	**Quercetin**	0	12.67	3.5
Chlorogenic	18.84	31.1	43.61	**Naringenin**	0	4.2	0.53
P-OH- benzoic	0.83	5.67	1.56	**Kampferol**	0	4.66	4.96
Benzoic	8.58	12.98	5.6	**Apigenin**	0.6	2.09	0.14
Caffeic	8.45	9.72	6.64	**leotuline**	39.18	133.58	21.48
Vanillic	17.13	2.35	9.15	**hesperdin**	318.46	1197.64	914.08
Caffeine	0	0	0				
Ferulic	1.77	1.4	3.79				
Ellagic	5.94	2.64	5.21				
Evanillic	2.53	1.3	1.86				
Salycilic	3.72	1.17	3.23				
Coumarin	1.56	1.53	4.9				
Cinnamic	45.69	18.46	138.1				

Table 6 shows the phenolic and flavonoid compounds present in carbonated hibiscus, tamarind and carob seed drinks.By extracting hibiscus, tamarind and carob in 10 times their volume of water, the contents of phenolic compounds and flavonoids decreased. It is observed that by the end of manufacturing soft drinks from hibiscus, tamarind and carob, carob recorded the highest content of phenolic compounds and the main compounds in the soft drink were (pyrogallol, cinnamic, catechin, gallic, catechol, chlorogenic and Vanillic). The antioxidant activity in carob can be attributed to the presence of gallic acid, protocathoic acid, catechin, hydroxybenzoic acid, and vanillic acid [73]. Tamarind recorded a lower content of phenolic compounds compared to carob. The predominant substances in tamarind soft drink were (catechein, pyrogallol, catechol, chlorogenic, cinnamic, benzoic and gallic). Hibiscus soft drink had the lowest content of phenolic compounds among the three soft drinks used and the most dominant phenolic compounds were (pyrogallol, catechol, catechin, cinnamic, gallic, chlorogenic, vanillic, 4-amino-benzoic, benzoic, benzoic, and caffeic). As for flavonoids, tamarind soft drink recorded the highest content of flavonoids and the predominant compounds were (hesperdin, leotuline, naringin, quercetin and quercetrin). Carob ranked second in terms of flavonoid content and the most dominant compounds were (hesperdin, leotuline, naringin, kampferol, quercetin and rosmarinic) while hibiscus soft drink recorded the lowest flavonoid content and the dominant substances were (hesperdin, leotuline and naringin).

CONCLUSION

Carob, tamarind, and hibiscus beverages have several nutritional and functional benefits, making them healthier alternatives to other soft drinks on the market. These findings indicate that carbonated beverages prepared from carob, tamarind, and hibiscus have significant quantities of nutrients vital to human health that have a variety of positive benefits, eventually contributing to a higher quality of life.The research focused on the development of a nutritious soft drink with varying levels of sweetening using zero-energy sweeteners. This is especially relevant considering typical soft drinks' high sugar and calorie content, which has been linked to a rise in weight-related disorders, obesity, and illness throughout the world. The quality analysis, which included sensory, chemical and physical attributes, yielded noteworthy results.The soft drinks of hibiscus and tamarind sweetened with erythritol at 1.5 g/200 ml had the best sensory qualities when compared to other concentrations. Carob pods soft drink sweetened with 0.5 g erythritol/200 ml had superior sensory features when compared to the control sample sweetened with sucrose sugar at 12 brix, which might be attributed to carob's high sugar content. Hibiscus carbonated beverage surpassed tamarind in terms of general acceptability, whereas carob carbonated beverage had the least agreeable sensory qualities. Hibiscus, tamarind and carob are a great choice for the production of carbonated beverages because they give the beverage desirable nutritional, cosmetic and medicinal qualities. Moreover, the simplicity of production and availability of raw materials allows for the stimulation of the economy by reducing dependence on multinational companies offering unhealthy or industrialized soft drinks.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors havedeclared that no competing interests exist.

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