

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 or industrialized soft drinks.

Keywords: carbonated Beverages, carob pods, roselle calyces, 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. CO₂ effervescence not only enhances the visual appeal of carbonated water and soft drinks, but also contributes to 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, allowing more to dissolve than would occur under standard atmospheric pressure. When the bottle is opened, the release of pressure allows the gas to escape from the solution, creating distinctive bubbles. 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 m⁻³, 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 0.1-0.2% 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 (CO₂) is a colorless, odorless, tasteless, inactive, non-toxic gas in nature that, when dissolved in water, produces carbonic acid. The highest concentration of CO₂ that can be dissolved in water is 8 grams per liter. The excess is often retained in the water only when the drink is under pressure. When the pressure is raised, or when the vessel is exposed to normal atmospheric pressure, the carbon dioxide begins to escape. Carbon dioxide also 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 consumption of soft drinks is a serious public health issue that can lead to cardiovascular disease. Chronic intake of refined sugars, especially fructose, has been linked to the development of arterial hypertension and cardiovascular dysregulation [7]. In addition, it raises blood pressure, triglycerides, visceral fat, resistance to the hypoglycemic effect of insulin, and HDL cholesterol levels, all of which increase the 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]. Consumption of sugar-filled beverages has been associated with a higher risk of type 2 diabetes [10]. One serving (334 ml) of sugary drinks per day doubled the risk of diabetes compared to consuming less than one serving (334 ml) per month in a long-term trial conducted over 8 years [11]. According to a different recent meta-analysis, consuming 334 milliliters of sugary drinks per day was associated with a higher risk of diabetes [12]. 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].

Sweeteners are the primary component (8-12% w/w) in the manufacturing of soft drinks. Erythritol is a sugar alcohol with 60-70% the sweetness of sucrose and no calories. It has no effect on blood sugar and is partly absorbed by humans and eliminated through feces and urine. Sugar alcohols are widely employed as sweeteners. Because of its low glycemic index, it is a good alternative for sugar in drinks. However, too much of it might cause bloating and gastrointestinal ache. Despite the superior taste of sweetened beverages made with sucrose (white sugar) or natural sweeteners such as honey, fruit juice, fructose or dextrose, these options contribute to increased calorie intake. So sweeteners are preferred over sugar because of their glycemic benefits and compatibility with a diabetic diet. Unlike sucrose and sugars containing glucose or fructose, which require insulin for metabolism, polyols such as erythritol do not require insulin for metabolism, making them more suitable for diabetics [13].

The demand for soft drinks is increasing daily, creating new opportunities for beverages to offer significant therapeutic, health and nutritional benefits. Beverages made from medicinal plants contain more nutrients and fewer artificial ingredients, making them excellent alternatives for consumers. According to a study by [14], the functional beverage industry is experiencing rapid growth, making it one of the fastest growing industries in the market. Juice consumption is known to promote both physical and mental health. Manufacturers are now focusing on developing unique products with enhanced nutritional value, higher vitamin and mineral content, and enhanced sensory appeal to meet the needs of their customers. Medicinal plant-based beverages are gaining popularity among consumers due to their rich content of antioxidants, including flavonoids, phenols, and anthocyanins, which offer numerous health benefits [15]. 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. Several studies have shown that anthocyanins, flavonoids and polyphenols have an additional cardioprotective effect, either through antioxidant processes or through other routes. H. sabdariffa extracts prevented LDL oxidation in vitro and lowered blood cholesterol levels in cholesterol-fed mice and rabbits [16-17]. The use of medicinal plants in the development of therapeutic food products has gained popularity as a result of the increasing focus on healthy living. Essential elements such as minerals, fiber, water-soluble vitamins, carotenoids, and polyphenols (including anthocyanins) are found in food plants such as hibiscus, carob, and tamarind. Thus, there is an increasing demand for nutritional beverages that contain sufficient bioactive compounds that can help prevent or treat certain human diseases [18]. Experimental trials have revealed that natural hibiscus extract exhibits potent antioxidant properties and has significant effects on hypertension, diabetes prevention, cardiovascular disease prevention, and liver protection

[19]. Research has shown that hibiscus drinks can positively affect the body's metabolism, helping to prevent obesity and fat accumulation in the liver. It should be noted that consuming one cup of hibiscus drink twice a day, which provides 250 mg of anthocyanins per day, is recommended for controlling high blood pressure [20]. The presence of anthocyanins in hibiscus is necessary to protect the body from oxidative stress that can contribute to the development of cardiovascular disorders [21]. Anthocyanins, known for their vasodilator properties, have been found to stimulate the production of nitric oxide (NO), which leads to vasodilation [22]. Consumption of anthocyanin-rich foods has been shown to have a positive effect on both lipid profile and platelet function [23]. [24] studied the chemical composition of red dry hibiscus cups and found that contained 11 moisture, 0.16% fat, 13.2% fiber, 7.88% protein, 10.6% ash and 57.16% carbohydrates respectively. The red hibiscus cups also contained 11 mg/100g of vitamin C, 60 mg/100g of calcium, 25 mg/100g of iron and 9 mg/100g of titratable total acidity respectively.

Carob fruit effectively prevents chronic diseases and provides significant health benefits such as lowering cholesterol, fighting cancer, regulating blood sugar, and acting as an antimicrobial agent [25]. Rich in natural bioactive compounds such as dietary fiber and polyphenols [26], its high antioxidant capacity is mainly attributed to its abundance of phenolic compounds, including flavonoids and condensed tannins [27]. Upon phytochemical analysis, the aqueous extract of carob pod was found to have a rich composition of polyphenols, flavonoids, and alkaloids. Particularly noteworthy are the large amounts of gallic acid, catechin, and protocatechuic acid present in the extract. In addition, the extract showed strong antioxidant activity, effectively inhibiting the formation of 2,2-diphenyl-1-picrylhydrazyl, hydroxyl and nitric oxide free radicals. Moreover, the extract showed a strong inhibitory effect against digestive enzymes (amylase, maltase, saccharase, and lactase). Furthermore, the extract showed anti-staphylococcus aureus, anti-Escherichia coli, anti-Candida albicans, and anti-herpes simplex virus type I (HSV-I) properties. The extract was also found to protect the erythrocyte membrane from hypotonic solution-induced hemolysis. In light of these findings, it is suggested that carob pods extract shows promise as a valuable source of bioactive antioxidants, antidiabetic, and antimicrobial compounds with potential applications in the pharmaceutical and dietary supplement fields [28]. [29] 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 is made up of pulp, seeds, peel and fiber. The pulp accounts for 30 to 50% of the ripe fruit and is high in reducing sugars, pectin, protein, fiber, and cellulose. Tamarind is also high in essential amino acids and phytochemicals, giving it antidiabetic, antibacterial and antioxidant properties [30]. The fruits have a moisture content of 38%. Tartaric acid is found in high concentrations in the pulp of the fruit [31]. The pulp consists of reducing sugars, pectin, protein, fiber, and cellulose that account for 30-50% of the ripe fruit. It has a high concentration of amino acids but is poor in protein and fat. It has a high content of minerals (calcium, phosphorus, copper and manganese) and the highest content of B vitamins. The percentages of the individual components do not vary by sample, with tartaric acid ranging from 8-18%, reducing sugars from 25-45%, pectin 2-3.5%, and protein 2-3% [32]. Tamarind fruit pulp contains many vitamins, minerals, acids, amino acids, invert sugar (25-30%), pectin, protein, fat, some pyranzines, and thiazoles. It also includes alkaloids, flavonoids, saponins, and tannins. Tamarind pulp has many biological activities, including lipid-lowering, antioxidant, antiferrous, analgesic, hepatoprotective, and antispasmodic properties [33]. It shows antibacterial activity against some bacteria, including *Aeromonas hydrophila* and *Hephaea alvei* [34], and can treat some bacterial diseases. It acts as a fever reducer, diuretic, carminative, diaphoretic, emollient, and hemorrhoidal stimulant. It is an anthelmintic, intestinal relaxant, stomach upset, jaundice, eye diseases, ulcers, and conjunctivitis [35]. Tamarind extract is considered an aphrodisiac, sperm stimulant, and safe for reproduction [36]. The benefits of tamarind fruit extract in the treatment of colon cancer have been associated with liver disease and protection against lipid peroxidation [37]. Hibiscus, tamarind, and carob drinks are particularly popular due to their medicinal benefits and cheap cost compared to other soft drinks, most of which come from overseas companies and drain the economy. The global demand for functional food products is on the rise, pushing the food industry to cater to the consumer base [38]. Consumers seek foods that are not only nutritious, but also convenient, tasty, and appealing [39]. The physical and chemical properties of foods play a crucial role in determining their sensory attributes, such as odor, taste, and appearance. These sensory characteristics ultimately influence consumer acceptance and preference [40]. Therefore, understanding the physical and chemical properties of food products is essential as they directly influence consumer responses [41]. The aim of this study was to develop low-calorie hibiscus, tamarind, and carob soft drinks with sensory and chemical evaluations of the resulting beverages.

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 °C, 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 added 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 [42] method. [43] recommended measuring the color index (absorbance at 420 nm). TPC was assessed using the Folin-Ciocalteu assay, using the procedure described by [44]. The results were represented in milligrams of Gallic acid. To determine the amount of flavonoids, the technique of [45] was utilized. The results were represented in mg of catechin. The antioxidant activity was measured using the technique published by [46].

2.2.2.2. HPLC Analysis of Phenolic Compounds

HPLC was used to quantify polyphenolic fractions, following [47] technique. Following sample preparation, the liquid was fed into the HPLC Hewlett 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 [47] approach. Following sample preparation, the sample was injected into a packed HPLC Hewlett (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 [48].

2.2.2.5. Sensory Analysis

An untrained panel evaluated carbonated beverages based on color, taste, scent, mouthfeel, and overall acceptability using a 9-point hedonic scale [49].

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 [50]. 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
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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		
Antioxidants activity%	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 [51-52-53-54-55]. 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 [56] 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 [57]. It also contains antioxidants such as flavonoids [58]. 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 [59]. 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 [60-61-28]. 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 [62]. 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 [63].

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

	Phenolic compounds $\mu\text{g}/100\text{g}$			Flavonoids $\mu\text{g}/100\text{g}$			
	Hibiscus	Tamarind	Carob	Hibiscus	Tamarind	Carob	
Pyrogallol	4050.35	880.89	1462.77	Rutin	8.44	11.51	11.09
Galic	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
Catechin	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				

Evaniilic	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 [64]. Moreover, their bioactivities may be related to their ability to inhibit lipoxygenase enzymes and scavenge free radicals [65]. 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 [66], many of which act as antioxidants. The most important phenolic compounds found in hibiscus (pyrogallol, catechin, catechol, 4-amino-benzoic, benzoic, chlorogenic, caffeic and gallic) while in tamarind (pyrogallol, catechol, catechin, 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, catechin, chlorogenic). Several studies have demonstrated that these molecules are known for their antioxidant and anticancer properties [67-68]. There are many data on carob components performed by HPLC, [26] 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 [69], cardiovascular disease [70], oxidative stress [71], and exhibiting neuroprotective properties [72].

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 [56].

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 sweetened 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 [73-74-57-58]. 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 [74]. 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 [75].

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	55	70	0.4
color index	0.31	0.33	0.21
Total phenolic mg/100g as Gallic	118.3	128.2	140.6
Total flavonoid mg/100g as catechin	122.6	173.9	158.2
anthocyanin mg/100g	536		
antioxidants	79.3	86.0	90.9
Mg (mg/100g)	24.2	4.7	1.7
Na (mg/100g)	0.8	6.6	12.0
K (mg/100g)	17.1	29.5	13.1
Mn (mg/100g)	5.0	0.2	0.3
Fe (mg/100g)	0.3	0.8	0.4
Ca (mg/100g)	56.0	30.4	27.5
Zn (mg/100g)	1.2	0.1	0.1
P(mg/100g)	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 [76]. Rosella drinks include numerous organic acids such as citric, malic, oxalic, and fumaric, which have antioxidant properties [77]. The levels found are expected to restrict microbial development [78]. 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 [79]. 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 [57]. The carbonization process helped maintain the acidity of the drink, resulting in an increase in vitamin C content [79]. 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/100g as gallic acid and flavonoids (122.6, 173.9 and 158.2 mg/100g as catechin). Phenolic compounds and flavonoids possess properties that enable them to act as antioxidants [80]. 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 g, 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 [81].

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 [82]. 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 [38]. The overall antioxidant activity of hibiscus extracts is the result of the combined contribution of phenolic compounds and organic acids [77]. 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 [83]. Moreover, anthocyanins not only contribute to the intense red

color of hibiscus drinks, but also play an important role in their antioxidant capacity [38]. 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/100g) while tamarind soft drink recorded the highest content of potassium, iron and phosphorus (29.5, 0.8 and 9.5 mg/100 g) while carob soft drink recorded the highest content of sodium (12 mg/100g).

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

	Carbonated beverages						
	Phenolic compounds $\mu\text{g}/100\text{g}$				Flavonoids $\mu\text{g}/100\text{g}$		
	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				
Salicylic	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, protocatechuic acid, catechin, hydroxybenzoic acid, and vanillic acid [84]. Tamarind recorded a lower content of phenolic compounds compared to carob. The predominant substances in tamarind soft drink were (catechin, 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

Hibiscus sabdariffa, tamarind and carob are promising functional foods rich in flavonoids, phenolic acids and tannins that have a significant effect in inhibiting alpha-glucosidase and alpha-amylase, which are involved in the conversion of carbohydrates into glucose, thus lowering blood sugar. The phenols and flavonoids provide protection against chronic diseases by interrupting chain oxidation reactions. 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.

References

1. Abu-Reidah IM, 2020. Carbonated beverages. In: Galanakis CM (Ed.), Trends in non-alcoholic beverages. Academic Press, London. 1-36.
2. Steen D, Ashurst PR (2008). Carbonated soft drinks, formulation and manufacture. 7th Ed. Blackwell Publishing, Oxford. 158-180.
3. Chaudhary V. Soft carbonated beverages. Beverages: Processing and technology. Scientific Publishers. Jodhpur, Rajasthan, (2018); 90-111.
4. World Health Organization (WHO) (2014). Report of the seventeenth WHOPES working group meeting: WHO/HQ, Geneva, 15-19 September 2014: review of Alpha-cypermethrin 250 WG-SB, Icon maxx, Netprotect LN, Chlorfenapyr 240 SC.
5. Poppitt SD. Beverage consumption: Are alcoholic and sugary drinks tipping the balance towards overweight and obesity? *Nutrients*. 2015;7:6700-18.
6. Malik VS, Popkin BM, Bray GA, Despres JP, Willett WC, Hu FB. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: A meta-analysis. *Diabetes Care*. 2010; 33(11):2477-83.
7. Kosova EC, Auinger P, Bremer AA. The relationship between sugar-sweetened beverage intake and cardiometabolic markers in young children. *J Acad Nutr Diet.*, 2013; 113(2): 219-27.
8. Gómez-Morales J, Lafisco M, Delgado-López JM, Sarda S, Drouet C. Progress on the preparation of nanocrystalline apatites and surface characterization: Overview of fundamental and applied aspects. *Progress in Crystal Growth and Characterization of Materials*, (2013); 59(1): 1-46.
9. Tucker LA, Tucker JM, Bailey BW, Lecheminant JD. A 4-year prospective study of soft drink consumption and weight gain: The role of calorie intake and physical activity. *Am J Health Promot.*, 2015; 29(4): 262-5.
10. Romaguera D, Norat T, Wark PA, Vergnaud AC, Schulze MB et al. Consumption of sweet beverages and type 2 diabetes incidence in European adults: Results from EPIC-InterAct. *Diabetologia*. 2013;56:1520-30.
11. Silva P, Duran S. Soft drinks, more than just a simple drink. *Rev Chil Nutr.*, 2014; 41(1): 90-7.
12. Hedrick VE, Comber DL, Estabrooks PA, Savla J, Davy BM. The beverage intake questionnaire: Determining initial validity and reliability. *J Am Diet Assoc.*, 2010; 110 (8):1227-32.
13. Grabitske HA, Slavin JL. Low-digestible carbohydrates in practice. *Journal of the American Dietetic Association*, (2008); 108(10), 1677-1681.
14. Mishra LK, Sangma D, Quality attributes, phytochemical profile and storage stability studies of functional ready to serve (RTS) drink made from blend of Aloe vera, sweet lime, amla and ginger. *Journal Food Science Technology*, 2017; 54:761-769.
15. Anwar A, Ali E, Nisar W, Ashraf S, Javed N, Anwar L, Tahir F.. Development and quality evaluation of functional carbonated pomegranate orange nectar. *Agrobiological Records*, (2023); 15: 52-58.
16. Chen CC, Hsu JD, Wang SF. "Hibiscus sabdariffa extract inhibits the development of atherosclerosis in cholesterol-fed rabbits," *Journal of Agricultural and Food Chemistry*, (2003); 51(18): 5472–5477.
17. Chen Y, Tseng SH, Lai HS, Chen WJ. Resveratrol-induced cellular apoptosis and cell cycle arrest in neuroblastoma cells and antitumor effects on neuroblastoma in mice. *Surgery*, (2004); 136(1):57–66. <https://doi.org/10.1016/j.surg.2004.01.017>
18. Lema AA, Mahmood NH, Khandaker MM, Abdulrahman MD. A review of Roselle anthocyanin stability profile and its potential role in postharvest deterioration. *Plant Science Today.*, (2022); 9(1): 119-131.
19. Chiu HF, Liao YR, Shen YC, Han YC, Golovinskaia O, Venkatakrishnan K, Wang CK. Improvement on blood pressure and skin using roselle drink: A clinical trial. *Journal of food biochemistry*, (2022); 46(10), e14287.
20. Ubom RE, Ugwu PI, Madueke SP, Okorie PO, Nwachukwu DC. AntiHypertensive Effects of Anthocyanins from Hibiscus sabdariffa Calyx on the ReninAngiotensin-Aldosterone System in Wistar Rats. *Nigerian Journal of Physiological Sciences.*, (2022); 37: 113-117. 10.54548/njps.v37i1.14.
21. Bell DR, Gochenaur K. Direct vasoactive and vasoprotective properties of anthocyanin-rich extracts. *Journal of applied physiology*, (2006); 100(4), 1164-1170.
22. Erlund I, Koli R, Alfthan G, Marniemi J, Puukka P, Mustonen P, Jula A. Favorable effects of berry consumption on platelet function, blood pressure, and HDL cholesterol. *The American journal of clinical nutrition*, (2008); 87(2): 323-331.
23. Alvarez-Suarez JM, Giampieri F, Tulipani S, Casoli T, Di Stefano G, GonzálezParamás AM, Battino M. Onemonth strawberry-rich anthocyanin supplementation ameliorates cardiovascular risk, oxidative stress markers and platelet activation in humans. *The Journal of Nutritional Biochemistry*, (2014); 25(3), 289-294.
24. Suliman AM, Ali AO, Idriss SEA, Abdulrahman MA. A comparative study on red and white karkade (Hibiscus sabdariffa L.) calyces, extracts and their products. *Pakistan Journal of Nutrition*, 2011; 10(7): 680-683.

25. Papaefstathiou E, Agapiou A, Giannopoulos S, Kokkinofa R. Nutritional characterization of carobs and traditional carob products. *Food Sci. Nutr.*, 2018; 6, 2151–2161.
26. Rtibi K, Jabri MA, Selmi S, Souli A, Sebai H, El-Benna J, Amri M, Marzouki L. Carob pods (*Ceratonia siliqua* L.) inhibit human neutrophils myeloperoxidase and in vitro ROS-scavenging activity. *RSC Adv.*, 2015; 5: 84207–84215.
27. Markis DP, Kefalas P. Carob pods (*Ceratonia siliqua* L.) as a source of polyphenolic antioxidants. *Food Technol. Biotechnol.* 2004, 42, 105–108.
28. Darwish WS, Khadr AES, Kamel MAEN, Abd Eldaim MA, El Sayed IET, Abdel-Bary HM, Ghareeb DA. Phytochemical characterization and evaluation of biological activities of Egyptian carob pods (*Ceratonia siliqua* L.) aqueous extract: In vitro study. *Plants*, (2021); 10(12): 2626.
29. Youssef SM, Abd El-Malak GA, Moussa ME. Utilization of carob pods in the production of alternative to cocoa powder. *J Agric Sci*, (2009); 17: 151-159.
30. Bidyalakshmi T, Sunita T, Kaukab S, Ravi Y. Engineering properties, processing and value addition of tamarind: A review. *International Journal of Bio-resource and Stress Management*, (2023); 14(11), 1530-1538.
31. Israel KS, Murthy C. Economics of tamarind seed powder processing unit in Karnataka. *International Journal of Commerce & Business Management*, 2019; 12(2): 67–72. <https://doi.org/10.15740/HAS/IJCBM/12.2/67-72>.
32. Ferrara L. Nutritional and pharmacological properties of *Tamarindus indica* L. *Journal of Nutrition Food and Science Forecast*, 2019; 2: 1012.
33. Menezes AP, Cerini SC, Barbalho SM, Guiguer EL (2016) *Tamarindus indica* L. a plant with multiple medicinal purposes. *J PharmacognPhytochem*, 5(3):50-54.
34. Adeniyi VO, Olaifa EF, Emikpe O, Band TS. Phytochemical components and antibacterial activity of *Tamarindus indica* Linn. Extracts against some pathogens. *Biotechnol J Int*, (2017); 17(2):1- 9.
35. Duke JA. *Hand book of legumes of world economic importance*. Plenum Press, New York, (1981); pp 228-230.
36. Raju VD, Kishore PS, Nanthagopal K, Ashok B. An experimental study on the effect of nanoparticles with novel tamarind seed methyl ester for diesel engine applications. *Energy conversion and management*, (2018); 164: 655-666.
37. Martinello F, Kannen V, Franco JJ, Gasparotto B, Sakita JY, Sugohara A, Garcia SB, Uyemura SA (2017) Chemopreventive effects of a *Tamarindus indica* fruit extract against colon carcinogenesis depends on the dietary cholesterol level in hamsters. *Food Chem Toxicol J* 107:261- 269. <https://doi.org/10.1016/j.fct.2017.07.005>
38. Wu HY, Yang KM, Chiang PY. Roselle anthocyanins: Antioxidant properties and stability to heat and pH. *Molecules*, (2018); 23(6): 1357.
39. Barret DM, Beaulieu JC, Shewfelt R. Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: Desirable levels, instrumental and sensory measurement, and the effects of processing. *Critical Reviews in Food Science and Nutrition*, (2010); 50(5): 369–389.
40. Piqueras-Fiszman B, Spence C. Sensory expectations based on product-extrinsic food cues: An interdisciplinary review of the empirical evidence and theoretical accounts. *Food Quality and Preference*, (2015); 40: 165–179.
41. Singham P, Birwal P, Yadav BK. Importance of objective and subjective measurement of food quality and their inter-relationship. *Journal of Food Processing & Technology*, (2015); 6(09): 488.
42. Association of Official Analytical Chemists (A.O.A.C.). (2012). *Official methods of analysis Association of Official Analytical Chemists international*, 19th edition, Gaithersburg, Maryland, 20877- 2417. USA.
43. Ranganna S. (1977). *Manual of Analysis Fruit and Vegetable products*. Tata MC. Graw Hill, publishing company limited, New Delhi, 150-161.
44. Zargoosh Z, Ghavam M, Bacchetta G, Tavili A. Effects of ecological factors on the antioxidant potential and total phenol content of *Scrophularia striata* Boiss. *Scientific reports*, (2019); 9(1): 16021.
45. Lin JY, Tang CY. Determination of total phenolic and flavonoid contents in selected fruits and vegetables, as well as their stimulatory effects on mouse splenocyte proliferation. *Food chemistry*, (2007); 101(1): 140-147.
46. Zhang D, Hamauzu Y. Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. *Food chemistry*, (2004); 88(4): 503-509.
47. Goupy P, Hugues M, Boivin P, Amiot MJ. Antioxidant composition and activity of barley (*Hordeum vulgare*) and malt extracts and of isolated phenolic compounds. *Journal of the Science of Food and Agriculture*, (1999); 79(12), 1625-1634.
48. Vikram B, Sikarwar PS. Development and Evaluation of Physico- Chemical Properties of Kinnow-Aonla-Aloe Vera Blended Squash. *International Journal Current Microbiology App. Science*, 2018; 7:113-122.
49. Sutwal R, Dhankhar J, Kindu P, Mehla R (2019). Development of low calorie jam by replacement of sugar with natural sweetener stevia. *International Journal Current Research Review* 11:9–16.
50. Steel RG, Torrie TH (1980). *Principles and procedures of statistics. A biometrical Approach*. McGraw Hill Book Comp., Inc., New York, USA.
51. Singh D, Wangchu L, Kumat Mood S. Processed products of Tamarind. *Natural Product Radiance*, (2007); 6 (4); 315 – 321.
52. Sulieman A, Ibnouf SM, Hassan KS. (2010). Extraction of Pectin from Tamarind Fruits (*Tamarindus indica* L.) and its Utilization in Jam Production. *International conference, Innovation in Food Science and Nutrition: Future challenges*, NRC, Cairo, 27 – 29 Sep.
53. Razali N, Matjunits S, Abdul-Muthalib AF, Subramaniam S, AbdulAziz A. Effect of various solvents on the extraction of antioxidant phenolics from the leaves, seed, veins and skins of *tamarindus Indica* L. *Food Chemistry*, (2012); 131: 441 – 448.

54. Youssef M; Kamal E, El-Manfaloty AM, Moshera M, Ali HM. Assessment of proximate chemical composition, nutritional status, fatty acid composition and phenolic compounds of carob (*Ceratonia siliqua* L.). *Food Pub. Health*, **2013**; 3: 304–308.
55. Gupta C, Prakash D, Gupta S. Studies on the antimicrobial activity of Tamarind (*Tamarindus indica*) and its potential as food bio-preservative. *International Food Research Journal*, (2014); 21 (6): 2437-2441.
56. Pacôme OA, Bernard DN Diabate Sékou, DjamanAllico Joseph, N'guessan Jean David, Kone Mongomaké and Kouakou Tanoh Hilaire, Phytochemical and Antioxidant of Roselle (*Hibiscus sabdariffa* L.) Petal Extracts. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, (2014); .4 (5): 1454 .
57. Ajala LO, Ogunlowo OM, Okafor MC, Onwukeme VI, Ezem SN. Chemo protective studies of some preservatives against spoilage microorganisms associated with stored roselle juice and their resultant effects on the juice's pH and ascorbic acid. *Current Advances in Chemistry and Biochemistry*, (2021); 9, 21-29.
58. Omoarukhe ED, Niamh H Paula J. The Effect of Cinnamon and Ginger Spices on Anthocyanins in Sweetened Roselle Beverages. *Beverages*, (2023); 9 (1): 24.
59. Goulas V, Stylos E, Chatziathanasiadou MV, Mavromoustakos T, Tzakos AG. Functional Components of Carob Fruit: Linking the Chemical and Biological Space. *Int. J. Mol. Sci.*, 2016, 17, 1875.
60. Qasem MA, Noordin MI, Arya A, Alsalahi A, Jayash SN. Evaluation of the glycemic effect of *Ceratonia siliqua* pods (Carob) on a streptozotocin-nicotinamide induced diabetic rat model. *Peer J*, 2018, 2018, 29844959.
61. Ayache SB, Saafi EB, Emhemmed F, Flamini G, Achour L, Muller CD. Biological activities of aqueous extracts from Carob. *Molecules*, 2020; 25, 1–16.
62. Custódio L, Patarra J, Alberício F, Neng NR, Nogueira JMF, Romano A. In vitro antioxidant and inhibitory activity of water decoctions of carob tree (*Ceratonia siliqua* L.) on cholinesterases, α -amylase and α -glucosidase. *Nat. Prod. Res.*, 2015; 29, 2155–2159.
63. Lin D, Xiao M, Zhao J, Li Z, Xing B, Li X, Kong M, Li L, Zhang Q, Liu Y. An overview of plant phenolic compounds and their importance in human nutrition and management of type 2 diabetes. *Molecules* 2016, 21, 1374.
64. Fang Z, Zhang M, Sun Y, Sun J. How to improve bayberry juice color quality: Effect of juice processing on bayberry anthocyanins and polyphenolic. *J. Agric. Food Chem.*, (2006); 54: 99-106.
65. Rathee JS, Hassarajani SA, Chattopadhyay S. Antioxidant activity of *Nyctanthes arbor-tristis* leaf extract. *Food Chem.*, (2007);103: 1350-1357.
66. Vattem DA, Maitin V. *Functional Foods, Nutraceuticals and Natural Products: Concepts and Applications*; DEStech Publications Inc.: Lancaster, PA, USA, 2016.
67. Ayaz FA, Torun H, Glew RH, Bak ZD, Chuang LT, Presley JM, Andrews R. Nutrient content of carob pod (*Ceratonia siliqua* L.) flour prepared commercially and domestically. *Plant Foods Hum. Nutr.*, 2009; 64, 286–292.
68. Torun H, Ayaz FA, Colak N, Grúz J, Strnad M. Phenolic acid content and free radical-scavenging activity of two differently processed Carob tree (*Ceratonia siliqua* L.) Pod. *Food Nutr. Sci.*, **2013**; 4: 547–553.
69. Harper CE, Patel BB, Wang J, Eltoum IA, Lamartiniere CA. Epigallocatechin-3-Gallate suppresses early stage, but not late stage prostate cancer in TRAMP mice: Mechanisms of action. *Prostate*, (2007); 67(14):1576–1589. <https://doi.org/10.1002/pros.20643>
70. Ghosh D, Scheepens A. Vascular action of polyphenols. *Molecular nutrition & food research*, (2009); 53(3): 322-331.
71. Akhlaghi M, Bandy B. Preconditioning and acute effects of flavonoids in protecting cardiomyocytes from oxidative cell death. *Oxid Med Cell Longev* 2012;9. <https://doi.org/10.1155/2012/782321>.
72. Wang J, Ferruzzi MG, Ho L, Blount J, Janle EM, Gong B, Pan Y, Gowda GAN, Raftery D, Arrieta-Cruz I, Sharma V, Cooper B, Lobo J, Simon JE, Zhang C, Cheng A, Qian X, Ono K, Teplow DB, Pavlides C, Dixon RA, Pasinetti GM. Brain-targeted proanthocyanidin metabolites for Alzheimer's disease treatment. *J Neurosci*, (2012); 32 (15): 5144.
73. Barajas-Ramírez JA, Gutiérrez-Salomón AL, Sáyago-Ayerdi SG. Concentration of roselle (*Hibiscus sabdariffa* L) and sucrose in beverages: Effects on physicochemical characteristics and acceptance. *Food Sci. Technol. Int.*, 2020; 27, 563–571.
74. Salami SO, Afolayan AJ. Suitability of Roselle \square *Hibiscus sabdariffa* L. as Raw Material for Soft Drink Production. *Journal of Food Quality*, 2020; (1): 8864142.
75. Makris DP, Kefalas P. "Carob pods (*Ceratonia siliqua* L.) As a source of polyphenolic antioxidants," *Food Technology and Biotechnology*, (2004); 42, (2): 105–108.
76. Jabeur I, Pereira E, Barros L, Calheta RC, Soković M, Oliveira MBPP, Ferreira ICFR. *Hibiscus sabdariffa* L. as a source of nutrients, bioactive compounds and colouring agents. *Food Res Int.* 2017 Oct;100(Pt 1):717-723. doi: 10.1016/j.foodres.2017.07.073. Epub 2017 Aug 2. PMID: 28873741.
77. Izquierdo-Vega JA, Arteaga-Badillo DA, Sánchez-Gutiérrez M, Morales-González JA, Vargas-Mendoza N, Gómez-Aldapa CA, Madrigal-Santillán, E. Organic acids from Roselle (*Hibiscus sabdariffa* L.)—A brief review of its pharmacological effects. *Biomedicines*, (2020); 8(5), 100.
78. Jiawei L, Dongbo N, Jiahui T, Tongyu S, Qiangwei M, Jianping L, Anshan S. (2023). The responses of organic acid production and microbial community to different carbon source additions during the anaerobic fermentation of chinese cabbage waste. *Bioresource Technology* 371 article 128602. 13.
79. Smith JS, Hui YH (2004). *Food processing principles and application*. Blackwell publishing, Iowa USA.
80. Patthamakanokporn O, Puwastien P, Nitithamyong A, Sirichakwal PP. Changes of antioxidant activity and total phenolic compounds during storage of selected fruits. *Journal Food Compos. Analysis*, 2008; 21:241-248.

81. Rodriguez-Solana R, Romano A, Moreno-Rojas JM. Carob pulp: A nutritional and functional by-product worldwide spread in the formulation of different food products and beverages. A Review. *Processes*, (2021); 9(7): 1146. <https://doi.org/10.3390/pr9071146>
82. Batra G, Lindbäck J, Becker RC, Harrington RA, Held C, James SK, Wallentin L. Biomarker-based prediction of recurrent ischemic events in patients with acute coronary syndromes. *Journal of the American College of Cardiology*, (2022); 80(18), 1735-1747.
83. Monteiro MJP, Costa AIA, Fliedel G, Cissé M, Bechoff A, Pallet D, Pintado MME. Chemical-sensory properties and consumer preference of hibiscus beverages produced by improved industrial processes. *Food Chemistry*, (2017); 225: 202-212.
84. Sroka Z, Cisowski W. Hydrogen peroxide scavenging, antioxidant and anti-radical activity of some phenolic acids. *Food Chem. Toxicol.*, **2003**; *41*: 753–758.

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