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Biological and Technological Evaluation of Sidr (*Ziziphus spina Christi L.*) Based on High Fat Diet as Anti-hyper Lipidemic Effects

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ABSTRACT

Sidr (*Ziziphus spina-ChristiL*) species are used in folk medicine. Nowadays, most people return to the use of natural plant medicines as a treatment for some diseases or for their protective effects. So, this study aimed to investigate the effect of *Ziziphus spina-ChristiL* (Sidr) on hyperlipidemic rats. Different Sidr plant parts were employed in this study (pulp, leaves, and seeds). Evaluations were done on the chemical compositions and flavonoid and phenol fractionation. Furthermore, lipid profiles and blood biological investigations were established. Moreover, several baked goods were made with Sidr pulp powder. Results showed that Sidr leaf powder had the highest contents of protein, fiber, and Fe (22.89 g/100, 14.29 g/100, and 39.73 mg/100 g, respectively). Sidr plant parts are rich in total phenol and total flavonoid contents. Catechin was the major compound in Sidr pulp (both powder and water extract). Also, rutin (a flavonoid compound) was the major compound in the water extract of Sidr pulp. The effect of rats fed a high-fat diet (HFD) and treated with Sidr pulp and water extracts of Sidr pulp, seeds and leaves on blood lipids was assessed. The rats in group 3, which were fed on HFD with 10% Sidr pulp powder, had an improved blood lipid profile compared with hyperlipidemic rats in other groups. Similar results were observed for kidney and liver functions, which were improved in hyperlipidemic rats fed on 10% Sidr pulp powder in their diet. On the other hand, due to the superior outcomes observed with the edible portion, specifically Sidr pulp, it was incorporated into the production of cakes and crackers. In terms of sensory qualities, the crackers Sidr formula scored higher than the cake Sidr formula. In conclusion, Sidr pulp powder increased the amount of total phenol, total flavonoid content, and DPPH-measured antioxidant activity in the cake and crackers.

1. Introduction

Ziziphus (Sidr pulps) are rich in minerals, fiber, vitamins, and polyphenols (Rashwan et al., 2020). Sidr is known as a multifunctional tree. Leaves, fruits, and fruit juices are good sources of bioactive components such as phenols, flavonoids, alkaloids, vitamin C, steroid tannins, botulinic acid, glycosides, and bioactive polysaccharides (Cadi et al., 2020). Folk medicine uses species of Christ's thorn to treat a wide range of ailments, including as diarrhea, fever, skin infections, obesity, liver complaints, urinary tract issues, and digestive disorders. (Abdel-Zaher et al., 2005 and Al-Sieni, 2014). The fruit of *Z. lotus* is an important source of nutrients as well as compounds with anti-inflammatory, anti-microbial, anti-fungal, anti-tumor, and immunosuppressive properties. Due to its great nutritional value, the fruit of the North African Ziziphus lotus is excellent and is often eaten straight from the tree. Minerals (Ca, Mg, Na, K, and P), carbohydrates, fatty acids, and proteins are plentiful in this organ.

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The fruit pulp of this plant has higher levels of vitamins A and C than the other portions (Widad et al., 2017). Moreover, distinguished The full potential of Ziziphus jujuba proteins in food preservation and medicine may not be realized due to their capacity to halt oxidative processes in hydrolysates and purified peptides. (Memarpoor-Yazdi, et al., 2013). In addition to its ability to effectively lower blood sugar and cholesterol levels in the serum of dietary hyperlipemic rats, Ziziphus jujuba seeds also possess anti-inflammatory properties. (Al-Reza and associates 2010). It has been established that this is a significant risk factor for coronary heart disease and a marker of early atherosclerosis before the artery wall develops obvious atherosclerotic changes (Bentley et al., 2002; Makni et al., 2008). Clinical studies have demonstrated that decreasing lipids lowers cardiovascular complications, morbidity, and death (Amundsen et al., 2002). Dietary supplementation with additional foods may help reduce lipid levels (El Rabey et al., 2013).

Following the administration of Christ's thorn leaves, hypercholesterolemic rats exhibited enhanced results in biochemical blood tests.

Moreover, the histological examination of the organs and tissues under scrutiny revealed a restoration of normal histology. This may be due to the fact that the leaves of Christ's thorns had anti-oxidant properties that improved liver and kidney functions, alleviated hyperlipidemia, and decreased lipid peroxide in hypercholesterolemic male rat models. It is possible that Christ's thorn's phenol component, which inhibits oxidative stress, is what gives it its anti-hyperlipidemic properties.

The aim of this study was to identify the nutritional value and the antioxidant activity of the Sidr plant and study its effect on the level of lipids in the blood by using Sidr pulp, seeds, and leaves, as well as the extracts of each of them. Also, the study includes evaluating the extent of consumer acceptance of cake and crackers containing different concentrations of Sidr pulp water extract (5, 10, 15, and 20%) and (5, 10, 15, 20, and 30%) powder, respectively, as a partial substitution for wheat flour.

2. Materials and Methods

Materials

Plant material and extract preparation

The sidr plant was purchased from a local market in Giza, Egypt. Sidr leaves were obtained from the Horticulture Research Institute, Agricultural Research Center (ARC), Giza, Egypt.

Preparation of Sidr fruits

The leaves of Sidr were free of dust and other foreign objects. The sidr leaves, pulp, and seeds were pulverized into particles that could pass through 20 mesh sieves after being dried for 10 to 12 hours at 50 to 55 °C in an oven.

Water Extract of Sidr Fruit Preparation

In a stainless-steel container, ten grams of Sidr fruit pulp, leaves, and seeds were each submerged in boiling tap water at a 10% w/v concentration. Boiling was sustained for 10 minutes, followed by allowing the container to cool to ambient room temperature. Subsequently, the mixture underwent filtration using cotton cloth to acquire the aqueous extract (Salem and Hassanan 2009).

Chemicals

1,1-diphenyl-2-picryl-hydrazyl (DPPH), quercetin dihydrate (2-(3,4-dihydroxyphenyl), and gallic acid were purchased from Sigma-Aldrich (St. Louis, MO, USA) along with the Folin-Ciocalteu phenol reagent (2N). Fisher Scientific (Fair Lawn, NJ, USA) provided the sodium hydroxide, aluminum chloride, sodium nitrite, sodium carbonate (99.8%), and HPLC solvents. The kits utilized in the study were supplied by the Gamma-Tread Company, located in Cairo, Egypt.

Animals

42 mature male Sprague-Dawley rats were purchased from Food Technology Research, House Animal Unit, ARC, Giza, Egypt.

Chemical analysis

The chemical composition of samples, including moisture, protein, fat, ash, and fiber, was determined according to (AOAC 2005). While available carbohydrate was calculated by difference, the energy of the samples was calculated using the appropriate factor as described by FAO/WHO/UNU

(1985).

Determination of minerals

The minerals Fe, K, Zn, Ca, Cr, and Na were digested using a microwave digestion system (Multiwave Go Plus) and determined using microwave plasma atomic emission spectroscopy (MP-AES) (model 4210, Agilent), Malaysia, according to (A.O.A.C. 2019).

Determination of phytochemical compounds

Total phenol was determined calorimetrically using the Folin-Ciocalteu reagent (as gallic acid equivalent) according to (Singleton et al., 1999). The total flavonoid was determined (as quercetin equivalent) according to (Marinova et al., 2005). The antioxidant activity was determined using the free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) as a reagent, according to (Cuendet et al., 1997).

Identification of some phenolic and flavonoid components by HPLC

Phenolic and flavonoid compounds using high-performance liquid chromatography (HPLC) for Sidr pulp, as well as water extracts from Sidr pulp, seeds, and leaves. The samples were prepared according to the method described by (Jakopic et al., 2009). The chromatographic conditions (mobile phase, gradient program, temperature of the column) were similar to those described by (Schieber et al., 2001).

Biological Study

Animals

Forty-two adult male Sprague-Dawley rats aged 4 weeks old (175.00±3 g) were obtained from the House Animals Unit, Food Technology Research Institute, and Agricultural Research Center. Then, they were housed in plastic cages and fed a basal diet according to (Reeves et al., 1993), and water was provided ad libitum for one week for the adaptation period. The conditional animal room temperature was maintained at 21 oC ± 2 oC with timed lighting for 12 hours and a relative air humidity of 40%. After the adaptation period, rats were randomly divided into seven groups. Group 1 (6 rats) continued on a basal diet as a negative control. Groups 2 to 7 were fed on a high-fat diet (HFD), as according to (Mehram et al., 2022) rising fats by 20% and decreasing protein by 10% induced malnutrition status for two weeks. Then, rats were treated with different parts of the Sidr plant, as shown in Table 1.

Experimental Design Animals

The experimental group of rats was subjected to a therapeutic intervention that included G3 fed on a diet containing 10% Sidr pulp powder. In addition, the remaining groups of rats (G4-G5-G6) received a daily oral dose of 2 ml of the water extract extracted from the pulp, seeds, and leaves of Sidr via stomach tube. This treatment protocol was continued for 8-weeks. At the end of the experimental period, rats were weighed, and blood was collected and euthanized using diethyl ether. Blood samples were collected from eye plexuses by placing a capillary tube into a dry, clean centrifuge glass tube without any coagulation to prepare serum. Blood samples were left to cool for 15 minutes. Then, the tubes were centrifuged for 15 minutes at 3000 rpm. Finally, the collected supernatant serum was kept frozen at -20^{o}C until analysis.

Biochemical Analysis

Total cholesterol (TC) was determined according to the method of (Rifai et al., 1999). Triglycerides (TG) were determined according to the method of (Bucolo and David 1973). High-density lipoproteins (HDL-c) were analyzed according to the method of (Assmann 1979). Low-density lipoproteins (LDL-c) and very low-density lipoproteins (VLDL-c) were estimated according to the method of (Lee and Nieman 1996). The atherogenic index (AI) and coronary risk index (CRI) were calculated according to the methods of (Abbott et al., 1988 and Adeneye et al., 2010). Kidney and liver functions: urea was determined according to (Tomas 1998a). Creatinine was determined according to the method of (Tomas 1998b). Urinary acid was determined according to the method of (Tietz 1990). Aspartate aminotransferase (AST) and alanine amino transferase (ALT) were estimated according to the method of (Moss and Henderson 1999).

Table 1. Design Experimental diets (g/100 g diet)

Ingredients	G1	G2	G3	G4*	G5*	G6*
Corn starch	57.8	49.8	41.43	49.8	49.8	49.8
Casine	12	10	9	10	10	10
Sucrose	10	10	10	10	10	10
Sunflower oil	10	20	19.81	20	20	20
Salt mixture	4	4	4	4	4	4
Vitamin mixture	1	1	1	1	1	1
Choline chloride	0.2	0.2	0.2	0.2	0.2	0.2
Cellules	5	5	4.56	5	5	5
Sidr pulp powder (10%)	-	-	10	-	-	-
Water extract of Sidr pulp	-	-	-	2ml	-	-
Water extract of Sidr leaves	-	-	-	-	2ml	-
Water extract of Sidr seeds	-	-	-	-	-	2ml

*2ml/rat/day by stomach tube.

Preparation of cake

In accordance with (Moraes et al., 2010)'s methodology, four different amounts of Sidr fruit powder (5%, 10%, 15%, and 20%) were substituted for wheat flour in the formulation of the Sidr cake. The temperature was kept at 180 ± 5 °C for the 40-minute baking process, and then it was cooled. An electric oven dryer was used to dry the cake samples at 50 °C for the entire night. The cakes were dried, ground, and then wrapped in plastic bags and kept at -20°C in a refrigerator freezer for later chemical analysis. Cake recipe ingredients were listed in (Table 2.). Observe that every sample was collected using a distinct type of water.

Table 2. Ingredients of cake formulas.

Ingredient (g)	Formulae				
	Control	5%	10%	15%	20%
Wheat flour	90	85	80	75	70
Milk powder	10	10	10	10	10
Sidr pulp powder	--	5	10	15	20
Sugar	60	60	60	60	60
Baking powder	5	5	5	5	5
Corn oil	50.0	50.0	50.0	50.0	50.0
Whole egg	90	90	90	90	90
Vanillin	2	2	2	2	2
Salt	1	1	1	1	1
Total	308	308	308	308	308

* Water as need requirement

Preparation of crackers

Preparing the crackers in accordance with (Sathe et al., 1981), the crackers were treated. Sidr Pulp powder was used in various ratios (5, 10, 15, 20, and 30%) in place of wheat flour. After being combined and shaped, the samples were heated to 175-205 °C for ten minutes. Following baking, the samples were allowed to cool, then sealed in plastic bags and stored at -20°C in a freezer until they underwent chemical analysis. Observe that distinct water was used for each sample collection.

Table 3. Ingredients of crackers formulas

Ingredient (g)	Sidr pulp powder					
	Control	5%	10%	15%	20%	30%
Wheat flour	100	95	90	85	80	70
Sidr pulp powder	--	5	10	15	20	30
Baking powder	1.5	1.5	1.5	1.5	1.5	1.5
Corn oil	10	10	10	10	10	10
Skim milk powder	1	1	1	1	1	1
Salt	1	1	1	1	1	1
Total	113.5	113.5	113.5	113.5	113.5	113.5

* Water as need requirement

Sensory evaluation

Sensory evaluation was conducted by twelve panelists from the staff of the Food Technology Research Institute at "ARC." The scoring scheme for cake was established for crust color (10), crumb color (20), taste (20), flavor (15), texture (15), grains (20), and overall acceptability (100). The cake under evaluation received quality scores based on (Soliman 1996). Cracker samples were evaluated for their sensory characteristics by twelve panelists from the staff of the Food Technology Research Institute at "ARC" The sensory attributes, including odor (20), taste (20), crispy (20), color (20), and general appearance (20), were evaluated by 10 trained members' panelists from the Food Technology Research Institute (Stone and Sidel, 2004).

Statistical Analysis

Statistical analyses were carried out by the SPSS-19 program. Data were expressed as means. The statistical analysis was performed using a one-way analysis of variance followed by Duncan's tests as outlined by (Snedecor and Cochran 1980).

3. Results and discussion

Chemical composition and some minerals were estimated in Sidr powder (pulp, seeds, and leaves). Results were recorded in Table 4. and Figure 1.

The data showed that Sidr leaves powder had the highest contents of protein, ash, fiber, and Fe (22.89%, 8.81%, 14.29%, and 39.73 mg/100g, respectively), while Sidr seeds powder had the highest contents of fat, energy, and Ca (5.966%, 380 kcal/100g, and 522.75 mg/100g, respectively). Sidr pulp had the highest levels of carbohydrates, Zn, and K contents (78.80%, 14.35 mg/100g, and 2611.44 mg/100g, respectively). (Atwaa et al., 2022), who found that Sidr fruit pulp (SFP) was low about approximately a quarter for chemical composition because distilled water was added to fruit pulp (1:1 W/V) to produce and improve the properties of fruit pulp. The fresh weight of each sample was therefore used to determine it.

Table 4. Chemical composition of sidr (pulp, seeds and leaves) powder (g/100g DW)

Items	Sidr pulp	Sidr seeds	Sidr leaves
Moisture	12.77^{a}±0.51	9.99^{b}±0.53	7.33^{c}±0.47
Protein	10.70^{c}±0.12	17.92^{b}±0.23	22.89^{a}±0.99
Fat	1.91^{c}±0.06	5.96^{a}±0.01	3.55^{b}±0.20
Ash	4.21^{c}±0.14	6.39^{b}±0.12	8.81^{a}±0.32
Fiber	4.37^{b}±0.15	5.93^{b}±0.77	14.29^{a}±0.73
Carbohydrates	78.81^{a}±0.34	63.80^{b}±0.68	50.46^{c}±1.10
Energy (Kcal/100g)	375±0.58	380±3.60	325±2.46

**Each value in a raw followed by the same letter is not significantly different at ($p \leq 0.05$).

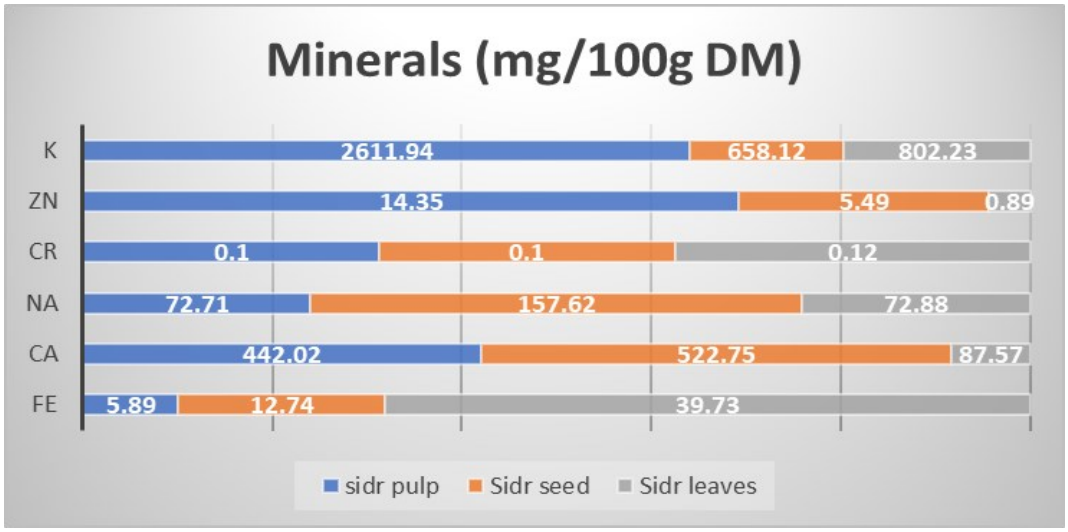
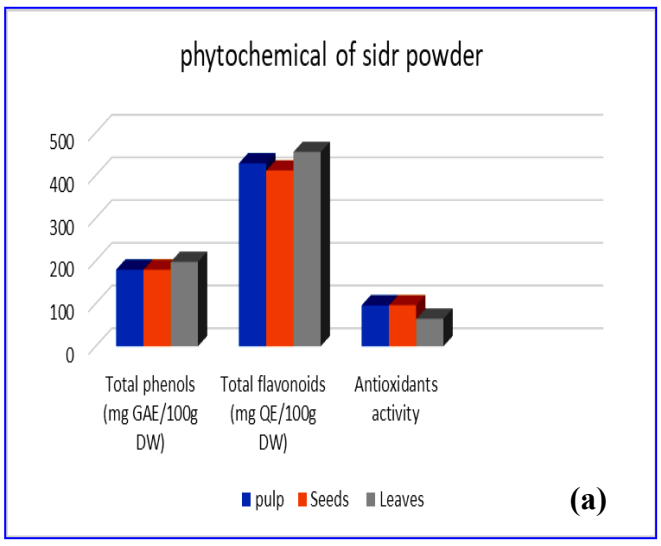


Figure 1. minerals content of Sidr powder (pulp, seeds, and leaves)

The data presented in Figures 2(a and b) showed some phytochemical contents for different parts of the Sidr plant, including powdered and water extracts. In general, water extracts of Sidr parts showed lower efficacy compared to Sidr parts powder. The total phenol content of Sidr powder ranged from 179.53 to 197.7 mg GAE/100 g DW. While water extracts ranged from 14.52 to 50.57 mg GAE/100 g DW, Also, the total flavonoids of Sidr powder ranged from 411.72 to 455.03 mg/100 g DW. While water extracts of Sidr parts ranged from 96.54 to 152.47 mg/100 g DW, Concerning the DPPH assay, the Sidr pulp had the highest levels of antioxidant activity by DPPH, both powder and water extract (96.02-79.98%), respectively. While Sidr leaves had the lowest levels of antioxidant activity by DPPH, both powder and water extract (64.59–53.02%).

These results were higher than previously reported by (Noutarki et al., 2017 and Elaloui et al., 2022), who reported that the difference in the total phenols in sidr leaf extract may be due to the method of extraction, type of solvent used, and the season in which samples were collected. As well, there was a correlation between total phenols and flavonoids and antioxidant activities (Bader et al., 2020). Moreover, these results are also higher than the previously studied results by (Atwaa et al., 2022), who determined the TP, TF, and DPPH of fruit Sidr as fresh weight.



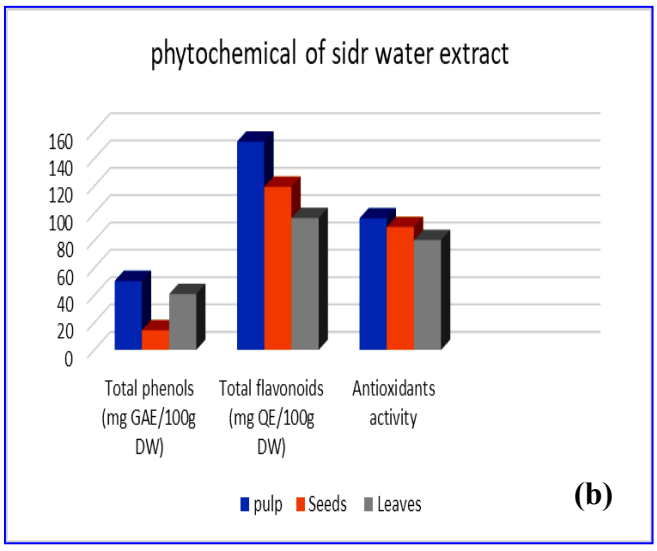


Figure 2. (a & b) Total phenols as Gallic acid (GAE), total flavonoids as quercetin (QE) and Antioxidants activity DPPH (%)

Fractionated and identified phenolic compounds of Sidr pulp powder and water extracts of seeds, leaves, and pulp by HPLC (mg/100 gDM) are shown in Table 5. The water extract of Sidr pulp had almost phenolic compounds, which were identified by standards in a high amount compared to other samples. Ellagic acid was the highest phenol compound found in the water extract of Sidr (457.32 mg/100g). As well, it is found in the water extract of Sidr leaves (1.89 mg/100g). There are some phenol compounds found in all samples (3-oh-tyrol, catechin, P-oH benzoic acid, benzoic acid, caffeic acid, and coumarin). (Wijaya et al., 2017) mentioned that high-performance liquid chromatography (HPLC) - identified phenolics and flavonoids show the existence of various phenolic and flavonoid components in each fraction that impart varying degrees of antioxidant activity.

Table 5. Fractionation of phenolic compounds of Sidr pulp and water extracts of pulp, seeds and leaves by HPLC (mg/100g DW)

Items	Pulp powder	Water extracts		
		Pulp	Seeds	Leaves
Pyrogallol	13.28	62.77	-	81.29
3 oH -Tyrosol	2.99	2.91	0.34	0.16
Catechol	1.42	1.35	0.33	-
4 amino benzoic acid	-	10.34	1.49	3.40
Catechin	179.63	153.93	2.32	5.43
Chlorogenic acid	-	35,95	12.70	4.48
P-oH benzoic acid	4.06	40.32	4.20	5.54
Benzoic acid	4.19	30.09	5.44	1.68
Caffeic acid	0.86	6.81	1.09	0.41
Caffeine	-	36.30	10.13	0.44
Ferulic acid	-	-	16.48	2.37
Ellagic acid	-	457.32	-	1.89
Salycilic acid	-	116.87	1.33	0.54
Coumarin	1.05	86.51	2.49	0.30

Fractionated and identified flavonoid compounds of Sidr pulp powder, water extracts of seeds, leaves, and fruits by HPLC (mg/100g DM) are presented in Table 6. The results of the flavonoid compounds in the water extract of Sidr pulp indicated that rutin and apigenin-6, a rabinose-8-glactose, contained a large amount of flavonoid content. While, (Elaloui et al., 2022), found that rutin was identified as a major compound in Sidr leaves, quercetin and caffeic acid were identified too. The results recorded in Table 7. showed that the effects of fed rats on HFD and treated with Sidr pulp and water extracts of fruits, seeds, and leaves on serum lipid. Generally, results showed that rats fed HFD treated with a water extract of Sidr seeds had the highest levels of TC, TG, LDL-c, and VLDL-c compared with other groups. Meanwhile, rats fed on HFD treated with Sidr pulp powder had the lowest levels of TC, TG, LDL-c, CRI, and AI compared with other rats fed on HFD. Also, the water extract of Sidr pulp had the best lowering lipid contents compared with water extracts of seeds and leaves. (Atwaa et al., 2022), who studied feeding the diabetic rat's fermented camel milk only and supplementing it with Sidr pulp (15%). Fermented camel milk supplemented with Sidr pulp caused improvements in TC, TG, and LDL compared to fermented camel milk alone. The anti-hyperlipidemic effects of Sidr pulp might be due to the fact that they are rich in many components, such as polyphenols and flavonoids. Thus, Sidr fruit contained a large amount of catechin, which has a function with enzymes to cause fat emulsification, hydrolysis, and micelle dissolution followed by absorption (Koo and Noh, 2007). Also, the antihyperlipidemic action might be due to stopping the chain reaction of lipid oxidation, maintaining the activity of HDL-binding porxonase by chelating oxidized metal ions, and preventing LDL oxidation (Kashyap et al., 2019).

Table 6. Fractionation of flavonoid compounds of Sidr pulp and water extracts of pulp, seeds and leaves by HPLC (mg/100g DW)

Flavonoid compounds	Pulp powder	Water extracts		
		Pulp	Seeds	Leaves
Apigenin 6- arabinose 8-glactose	-	88.40	9.12	55.47
Apigenin 6- rhaminose 8-glucose	-	38.15	-	0.12
Rutin	2.54	281.31	4.02	2.59
Naringin	-	-	6.78	3.57
Hesperdine	14.45	-	16.64	0.95
Rosmarinic acid	0.59	65.82	-	-
Qurectrin	7.10	-	-	5.42
Qurcetin	-	62.99	7.86	-
Naringinen	2.65	4.10	0.68	-
Kaempferol 3-2-P- Coumaryl glucose	-	50.03	1.71	-
Kaempferol	0.17	18.03	0.45	-
Apigenin	0.09	3.11	0.03	0.18

Table 7. Effect of feeding rats on HFD and treated Sidr pulp powder, water extracts of Sidr pulp, leaves and seeds on serum lipids (mg/dl)

Items	**Controls groups**		**Sidr pulp powder**	**Water extracts**		
	(-)	(+)		Pulp	Seeds	Leaves
T.C	72.33^{c}±3.51	90.00±2.0	78.50^{bc}±6.50	84.33^{ab}±4.04	91.33^{a}±4.16	90.00^{a}±2.00
TG	47.33^{b}±5.03	55.50^{b}±2.5	48.5^{b}±0.50	54.0^{b}±6.0	78.00^{a}±16.00	59.50^{b}±6.5
HDL-C	42.66^{a}±0.57	39.00^{a}±9.00	42.50^{a}±0.50	42.00^{a}±0.00	42.00^{a}±0.00	44.50^{a}±3.50
LDL-C	26.0^{a}±6.93	31.50^{a}±5.50	26.50^{a}±7.5	35.00^{a}±7.0	38.00^{a}±3.00	35.50^{a}±8.50
VLDL-C	9.47^{b}±1.01	11.10^{b}±0.50	9.70^{b}±0.10	10.80^{b}±1.20	15.60^{a}±3.20	11.90^{b}±1.30
CRI	1.69^{b}±0.07	2.39^{a}±0.53	1.85^{b}±0.18	2.01^{ab}±0.96	2.17^{ab}±0.10	2.03^{ab}±0.18
AI	0.60^{a}±0.15	0.82^{a}±0.05	0.63^{a}±0.18	0.83^{a}±0.17	0.90^{a}±0.07	0.81^{a}±0.26

*Each value in a row followed by the same letter is not significantly different at ($p \leq 0.05$). **CRI; coronary risk index ***AI; atherogenic index

Results in Table 8. showed that the effects of fed rats on HFD and treated with Sidr pulp powder and water extracts of Sidr pulp, seeds, and leaves on liver and kidney functions. Rats (G1) in the in the negative control group had the lowest levels of kidney and liver function, while rats (G2) in the in the positive control group had the highest levels of kidney and liver function. These groups were treated with Sidr powder and water extracts of fruit seeds and leaves. The results show improvements in kidney and liver functions. Thus, Sidr pulp powder causes improvements in serum creatinine and uric acid, as well as kidney and AST liver function. While the water extract of Sidr seeds and leaves improved ALT and liver function, (Atwaa et al., 2022), who stated that when feeding the diabetic rats fermented camel milk only and supplemented with Sidr pulp (15%), the fermented camel milk supplemented with Sidr pulp improved liver functions, which showed a significant reduction in plasma AST and ALT levels. The hepatic protective effects of Sidr fruit could be attributed to its high phenol and flavone contents, which have antioxidant properties by trapping free radicals (Khouchlaa et al., 2017). Moreover, (Hafiz et al., 2019) concluded that *zizphus spina-christi* leaf extracts had a protective role against plasmodium in function, which reduced the ALT and AST enzymes. Concerning kidney functions, the results agreed with (Atwaa et al., 2022), who studied that feeding the diabetic rats fermented camel milk only and supplemented with Sidr fruit pulp (15%).

Their results showed that diabetic rats treated with a fermented camel milk supplement with Sidr pulp (15%) had a highly significant decrease in creatinine and urea. Through biological experiments, the results showed that Sidr pulp powder had the highest positive effects on improving the level of blood fat compared to rats that suffer from high levels of blood fat in other groups. It is also characterized by its high content of antioxidants, and accordingly, Sidr pulp powder has been introduced in the manufacture of both cakes and crackers in different proportions.

Sensory evaluation for Sidr cake and crackers is shown in Table 9. and Figure 3. Generally, all percentages of Sidr pulp powder were acceptable to panelists. The cake sample, which contained 5% Sidr pulp powder, had the best scores for all characters. While there were no significant differences in flavor between the cake samples to which Sidr pulp powder was added compared to the control, The radar chart reveals that the cracker sample incorporating 15% Sidr pulp powder attained the highest scores across all evaluated characteristics. Subsequently, the samples containing 5% and 20% Sidr powder followed suit, as evident from the external shape's respective areas, which measured 5, 4.9, and 4.8, respectively, compared to the control's score of 4.2. (Atwaa et al., 2022) found that sidr pulp improved the sensory properties of camel milk. Also, the same author reported that the improvement was proportional to the supplementation ratio. Thus, 15% of Sidr pulp had the highest scores.

Table 8. Effect of feeding rats on HFD and treated Sidr pulp powder, water extracts of Sidr pulp, leaves and seeds on liver and kidney functions.

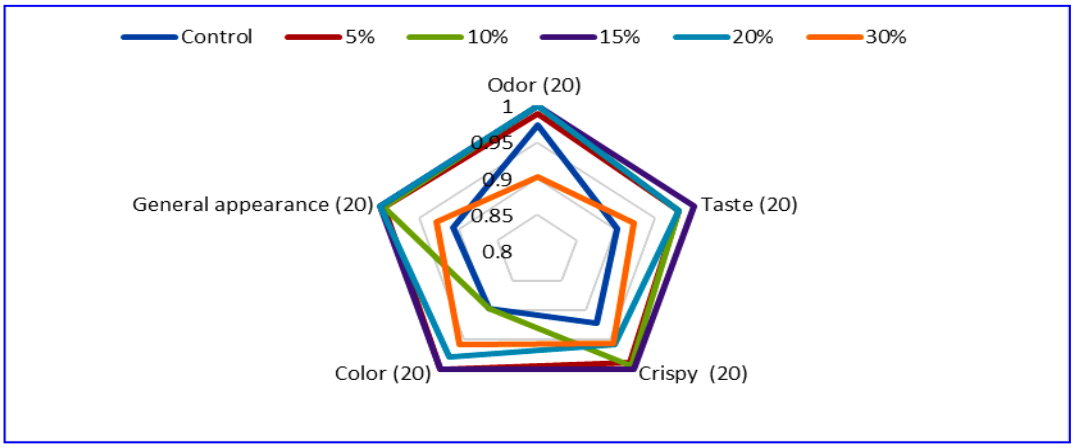
Items	Controls groups		Sidr pulp powder G3	Water extracts		
	G1(-ve)	G2(+ve)		Pulp G4	Seeds G6	Leaves G5
Urea (mg/dl)	$33.10^{d}\pm0.50$	$85.50^{a}\pm1.15$	$53.50^{b}\pm1.50$	$50.00^{c}\pm1.00$	$53.00^{b}\pm1.00$	$51.50^{bc}\pm2.78$
Creatinine (mg/dl)	$0.43^{c}\pm0.04$	$1.50^{a}\pm0.39$	$1.05^{b}\pm0.25$	$1.47^{a}\pm0.15$	$1.21^{ab}\pm0.01$	$1.10^{ab}\pm0.20$
Uric acid (/dl)	$1.38^{c}\pm0.40$	$2.40^{a}\pm0.10$	$2.08^{b}\pm0.23$	$2.20^{ab}\pm0.10$	$2.25^{ab}\pm0.15$	$2.20^{ab}\pm0.10$
ALT(U/L) *	$24.00^{d}\pm0.70$	$61.50^{a}\pm1.50$	$43.00^{b}\pm3.00$	$33.50^{c}\pm1.50$	$31.00^{c}\pm1.00$	$31.50^{c}\pm0.50$
AST(U/L) *	$42.50^{d}\pm0.90$	$104.3^{a}\pm4.04$	$55.50^{c}\pm3.50$	$63.00^{b}\pm3.00$	$66.50^{b}\pm2.50$	$62.00^{b}\pm2.00$

* ALT; Alanine aminotransferase, AST; Aspartate aminotransferase.
** Each value in a row followed by the same letter is not significantly different at ($p \leq 0.05$).

Table 9. Sensory evaluation of Sidr cake

Sample	Crust color (10)	Crumb color (20)	Flavor (15)	Texture (15)	Taste (20)	Grains (20)	Overall acceptability (100)
Control	$9.3^{a}\pm0.213$	$19^{a}\pm0.258$	$13.7^{a}\pm0.454$	$14.15^{a}\pm0.183$	$18.60^{a}\pm0.581$	$19^{a}\pm0.258$	$93.80^{a}\pm1.085$
5%	$8.25^{ab}\pm0.454$	$17.4^{ab}\pm0.581$	$13.30^{a}\pm0.335$	$13.20^{ab}\pm0.359$	$17.30^{ab}\pm0.517$	$18.1^{ab}\pm0.276$	$87.55^{b}\pm2.221$
10%	$7.8^{bc}\pm0.442$	$17.1^{b}\pm0.585$	$13.0^{a}\pm0.447$	$12.90^{ab}\pm0.348$	$16.80^{b}\pm0.592$	$17.2^{bc}\pm0.359$	$84.80^{bc}\pm1.936$
15%	$7.8^{bc}\pm0.466$	$16.2^{b}\pm0.891$	$13.70^{a}\pm0.517$	$13.10^{ab}\pm0.721$	$16.70^{b}\pm0.335$	$16.90^{c}\pm0.314$	$84.40^{bc}\pm2.334$
20%	$6.9^{c}\pm0.378$	$16.3^{b}\pm0.300$	$12.60^{a}\pm0.400$	$12.70^{b}\pm0.300$	$16.0^{b}\pm0.557$	$15.90^{d}\pm0.458$	$80.40^{c}\pm1.687$

* Each value in a column followed by the same letter is not significantly different at ($p \leq 0.05$).



samples	Control	5%	10%	15%	20%	30%
area	4.2	4.9	4.7	5	4.8	4.3

Figure 3. Sensory evaluation of Sidr crackers

Results in Table 10. showed the effect of adding sider pulp powder to cake and cracker products on total phenol, flavonoids, and antioxidant activity by DPPH. Generally, increasing the percentage of Sidr pulp powder causes an increase in total phenols, total flavonoids, and antioxidant activity by DPPH. Moreover, cake samples that contained Sidr pulp powder (different percentages) had more total phenols, total flavonoids, and antioxidant activity by DPPH than cracker samples. This result may be due to the quality and quantity of some ingredients, like whole eggs. (Falciano et al., 2022 and Atwaa et al., 2022) studied the incorporation cause of the increase in total phenol and flavonoid content.

Table 10. Phytochemicals for cake and crackers Sidr formulas

Samples	Antioxidants activity DPPH (%)	Total phenols (mg GAE/100g DW)	Total flavonoids (mg QE/100g DW)
Cake with Sidr pulp			
control	$64.12^{e}\pm0.173$	$317.63^{e}\pm2.02$	$322.03^{e}\pm1.61$
Sidr pulp 5%	$68.93^{d}\pm0.970$	$399.71^{d}\pm1.61$	$442.62^{d}\pm2.93$
Sidr pulp10%	$75.42^{c}\pm1.351$	$458.01^{c}\pm2.17$	$553.94^{c}\pm0.36$
Sidr pulp15%	$81.64^{b}\pm0.508$	$559.55^{b}\pm2.40$	$621.99^{b}\pm2.55$
Sidr pulp20%	$84.46^{a}\pm0.329$	$640.94^{a}\pm1.89$	$890.29^{a}\pm1.37$
Crackers with Sidr pulp			
Control	$31.07^{d}\pm1.29$	$84.27^{f}\pm3.15$	$108.53^{f}\pm1.22$
Sidr pulp5%	$52.97^{c}\pm2.39$	$269.63^{d}\pm1.75$	$122.06^{e}\pm4.34$
Sidr pulp10%	$58.76^{b}\pm2.04$	$262.06^{e}\pm3.09$	$132.13^{d}\pm4.09$
Sidr pulp15%	$58.75^{b}\pm1.130$	$279.20^{c}\pm5.86$	$142.788^{c}\pm4.75$
Sidr pulp20%	$60.31^{b}\pm2.01$	$304.53^{b}\pm3.50$	$148.38^{b}\pm4.47$
Sidr pulp30%	$78.53^{a}\pm2.33$	$317.33^{a}\pm1.48$	$150.63^{a}\pm2.44$

4. Conclusion

The present study highlights the importance of *Ziziphus spina-christi* by identifying its different parts, including pulp, seeds, and leaves, to evaluate its nutritional and health properties. The plant shows a high content of nutrients and is characterized by a noticeable concentration of minerals and various phenolic components. These compounds exhibit strong antioxidant properties and also have health properties that positively affect the serum lipid profile. The results highlight the potential of *Z. spina-christi* as a valuable source of both nutrients and health-promoting elements, encouraging further exploration of its applications in the food and drug fields.

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