Original Article

Impact of different solvents on extraction yield, phenolic composition, in vitro antioxidant and antibacterial activities of deseeded *Opuntia stricta* fruit

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Abstract
Opuntia stricta the shrubby plant is naturally occurring in all parts of the world used as popular ornamental and is known to have medicinal properties due to its phytochemical compositions. In this study, the effect of solvents (80% ethanol, 80% methanol and 80% acetone (v/v) in water) on the extraction yield, total phenolic content (TPC), total flavonoid content (TFC), antioxidant activity and antibacterial activity of *Opuntia stricta* fruit were investigated. For the antioxidant activity assay, three different *in-vitro* methods DPPH, ABTS and FRAP were followed. The One-way ANOVA calculations showed that the extraction solvents influenced greatly and significantly the TPC, TFC and antioxidant capacity. Overall, 80% ethanol showed highest percentage of extraction yield while 80% acetone extract showed the lowest extraction yield but the highest TPC, TFC and antioxidant activity of *Opuntia stricta* fruit. In addition, Pearson's correlation analysis proved a strong correlation between TPC, TFC and all antioxidant methods used. The antibacterial tests demonstrated that 80% methanol and 80% acetone extracts exhibited the highest zones of inhibition (11.66 and 11.33 mm respectively, $p > 0.05$) against *Salmonella thyphimurium*. Likewise, the 80% acetone extract revealed the best inhibitory effect contra *Escherichia coli* ($p > 0.05$) with an inhibition zone of 11 cm. Unfortunately, it was observed that gram-positive bacteria were less sensitive to all *Opuntia stricta* extracts compared to the gram-negative bacteria.

Keywords *Opuntia stricta* · Solvent extraction · Polyphenols · Antioxidant activity · Bacterial activity

1 Introduction

Opuntia stricta is a member of *Cactaceae* family and has been grown widely around the world in arid and semi-arid zones owing to their low water requirements [1, 2]. *O. stricta* is very famous in Tunisia and used as an ornamental plant in parks, botanical gardens and as potted plant. *O. stricta* is a spiny perennial succulent shrub of evergreen low-growing plant (nearly up to 200 cm tall) with relatively large-flattened and elongated stem segments, and red-dish-purple fruits [3].

The *Opuntia* species are prominent and have been used in conventional medicine earlier for treatment of a range of ailments and it is a promising source of bioactive compounds [4]. The phytochemical composition and different bioactivities of different plant parts have been reported. Phytochemical screening of *O. stricta* fruits and cladodes are reported to contain flavonoids glycosides such as

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isorhamnetin-3-O-rutinoside, Kaempferol-3-O-rutinoside and phenolic acids as well as vitamins A, C and E [5–7]. It was proven that *O. stricta* is an excellent source of betacyanin pigments with high concentrations of betanin, isobetanin and betanidin as well as betanidin-5-O-glucoside and betanidin-6-O-glucoside [2, 6]. *O. stricta* was utilized for the remedy of chronic diseases for many centuries and the fruits are said to possess a value in treatment of diabetes [4]. Moreover, *O. stricta* extracts obtained from flowers and whole fruits or peels exhibited many pharmacological activities such as anti-spermatogenic, hypotensive, anti-oxidant, antibacterial, anti-inflammatory, antiviral, analgesic and anticancer [8–16]. These beneficial medicinal features are as a result of their chemical contents of antioxidants, pigments, and phenolic acids [17, 18].

Kharat et al. study revealed that the natural extract of red prickly pear (*O. stricta*) was rich in polysaccharides, polyphenols and flavonoids, which displayed strong antioxidant and antibacterial activities due to the synergistic effect of these natural ingredients [19]. In a recent study, aqueous extracts of fruits peel exhibited higher antioxidant and anti-bacterial powers compared to cladodes. These effects have been linked to the presence of phenolic compounds and flavonoids especially quinic acid and hyperoside [20]. Moreover, it was found that the essential oil of *O. stricta F* had strong antibacterial and antifungal effectiveness against standard strains of *P. aerugiosa, B. cerus, E. colli, C. Albicans and B. licheniformis*. This antimicrobial efficacy was linked with the presence of thymol as a dominant constituent [21].

Koubaa et al. have investigated solvent extraction of *O. stricta* peels grown in Tunisia and noticed that the extract exhibited high in vitro antioxidant and antibacterial potentials [12]. The physicochemical features of the Tunisian *O. stricta* seed oils were investigated and the compositions of fatty acids, triacylglycerols, phytosterols, and tocopherols were studied. The compliance of fatty acid methyl esters indicators with the American Society for Testing and Materials, European Union and the Indian Standards, for biodiesel properties was proved [22]. Recently, Surup et al. have detected two-14-ring-membered cyclopeptide alkaloids by fractionation of the extracts of *O. stricta* var. dillenii fruits using HPCCC [23].

To the best of our knowledge, there is no previous published papers investigated the effect of solvent on extraction yield, phenolic composition, anti-oxidant and antibacterial activities of deseeded *Opuntia stricta* fruit. In this context, this work aimed at examining, for the first time, the impact of various solvent concentrations on extraction yield, TPC, TFC and antioxidant activities using DPPH, ABTS and FRAP assays as well as antibacterial activities of deseeded *Opuntia stricta Haw.* fruit extracts.

2 Materials and methods

2.1 Plant material

The plant (*Opuntia stricta Haw.*) was identified by Dr Haidar Abdalgadir Mohamed an experienced taxonomist (Biology Department, Faculty of Science, Albaha University). The fruits were washed, air-dried and crushed by an electric mixer. The seeds were segregated from the purple juice which was frozen and then lyophilized (yield = 10.32 w/w%). After this, 3 gm of lyophilized samples were defatted by vigorous agitation with n-hexane twice. After discarding of the n-hexane layer, the phenolic compounds were extracted twice from the defatted residue by maceration extraction technique using 15 mL different solvents (acetone/ water (80/20 v/v), methanol/ water (80/20 v/v) and ethanol/ water (80/20 v/v). The obtained extracts were filtered and concentrated yielding to solids of different colors ranging from orange-red (hydro acetone) to red (hydro methanol) and wine (hydro ethanol). The freeze-dried extracts were stowed for further analysis. The extraction percent yield (w/w) was calculated as follows.

$$\%Yield = \frac{The\ mass\ of\ the\ extract\ after\ solvent\ evaporation}{The\ mass\ of\ the\ lyophilized\ plant\ material} \times 100$$

2.2 Solvents and chemicals

All solvents and chemicals were of analytical grade. Folin–Ciocalteu, quercetin, Butylated hydroxytoluene (BHT), gallic acid, 2,2-diphenyl-1-picrylhydrazyl (DPPH), (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), $FeCl_3$, 2,4,6-tripyridyl-S-triazine (TPTZ), potassium ferricyanide [$K_3Fe(CN)_6$] and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (trolox) were from Sigma–Aldrich Inc. (Steinheim, Germany).

2.3 Total polyphenol content (TPC)

Total polyphenol content was measured spectrophotometrically using Folin-Ciocalteu reagent adapted from Pourmorad et al. [24]. Briefly, 500 µL aliquot of extract solution was blended with Folin-Ciocalteu aqueous solution (2.5 mL, 10% v/v) reagent and of Na_2CO_3 (2 mL, 1 M). The obtained solution was kept for 2 h. The optical density of the obtained dark blue solution was read at 760 nm. TPC was presented as microgram gallic acid equivalents (µg GAE/mg dry weight).

2.4 Total flavonoid content (TFC)

TFC was assessed according to Pourmorad et al. slightly modified method [24]. An aliquot of extract solution (500 µL) was blended with 1.5 mL methanol, 0.1 mL of $AlCl_3$ (10%), 0.1 mL of Na_2CO_3 (1 M) and 2.8 mL of water and kept for half an hour. The optical density was recorded at 430 nm. TFC was assessed as microgram of quercetin equivalents (µg QE/mg dry weight).

2.5 Antioxidant activity

2.5.1 DPPH assay

The scavenging activity of extracts against DPPH$^{\bullet}$ was established as described by Brand-Williams et al. slightly modified [25]. Different concentrations of extracts (1 mL) were mixed with a methanolic solution of DPPH (2 mL, 10^{-4} M). The obtained solution was shaken gently and left to stand for 1 h. The optical density was recorded against a blank at 515 nm. High free radical scavenging activities is indicated by low absorbance values. The scavenging activity was estimated utilizing the DPPH inhibition percentage as follows:

$$\%DPPH\ radical\ scavenging = \frac{A_0 - A_s}{A_0} \times 100$$

where A_0: control absorbance and A_s: the sample absorbance. The sample concentration providing 50% of inhibition (IC_{50}) expressed as mg/mL, was determined from the plotted curve of inhibition using several extract concentrations and compared to quercetin, BHT and trolox as positive controls.

2.5.2 ABTS radical scavenging assay

The ABTS free radical-scavenging assay was determined following the method reported by Re et al. in which 7 mM ABTS solution was mixed with 2.45 mM potassium persulfate and allowed to stand for 12–16 h in order to produce $ABTS^{+\bullet}$ [26]. The blue-green ABTS solution was diluted to obtain an absorbance of 0.7 at 734 nm prior to assay. 150 µL of appropriately diluted samples was mixed with2850 µL of ABTS solution and kept for half an hour. Then, the absorbance was read at 430 nm. The ABTS radical scavenging potential of samples was presented as IC_{50} (the concentration necessary to reduce 50% of $ABTS^{+}$) and compared to Trolox as positive control. The procedure was like the DPPH scavenging assay.

2.5.3 Ferric reducing antioxidant power (FRAP) assay

The FRAP of extracts was studied using the method reported by Binsan et al. with minor modifications [27]. Briefly, the FRAP solution was made by adding 0.3 M acetate buffer (pH 3.6), 0.01 M TPTZ to 0.02 M $FeCl_3$ in a 10:1:1 ratio. The mixture was kept at 37 °C for half an hour. Different concentrations of extracts (150 µL) were added to the FRAP solution and the absorbance was read at 593 nm. Increased reaction mixture absorbance indicated increased reducing power. The sample concentration providing 0.5 of absorbance (EC_{50}) was calculated by plotting absorbance against the corresponding sample concentration and compared to Trolox.

2.6 Antibacterial activity

2.6.1 Bacterial strains and growth conditions

Four bacterial strains were used to evaluate the antibacterial capacity of the plant extracts: two gram-negative namely *Escherichia coli* (ATCC 8739) and *Salmonella typhimurium* ATCC 14,028 and two gram-positive namely *Enterococcus feacium* (ATCC 19,434) and *Streptococcus agalactiae* (ATCC 13,813). Apart from *Streptococcus agalactiae*, which was isolated in the National Institute of Applied Sciences (Tunis), the remaining strains were provided by the Pasteur Institute (Paris, France). Bacterial strains were cultured overnight at 37 °C in Mueller–Hinton (MH) agar nutrient.

2.6.2 Disk diffusion method

For the determination of the antibacterial activity, the disk diffusion method was used according to the National Committee for Clinical Laboratory Standards (NCCLS) [28]. Briefly, the bacterial suspension (100 µL/10^8 CFU/mL) was spread on the MH solid media plate. Sterile filter paper disk (6 mm in diameter) was soaked with 15 µL of the extracts (dissolved in dimethylsulfoxide) and placed on the inoculated plates and kept at 4 °C for 2 h. Then, they were kept at 37 °C for 1 day. Amoxicillin antibacterial drug was used as standard reference for comparison. The definite inhibition zone surrounding the paper disk was measured accurately in mm.

2.7 Statistical analysis

All assays were repeated thrice and the data was statistically reported as average ± standard deviation (SD).

One-Way Analysis of Variance (ANOVA) using the SPSS 22.0 software. Differences among means were analyzed using Tukey test ($p < 0.05$). Pearson's correlation coefficients were calculated for TPC, TFC, and antioxidant activities.

3 Results and discussion

3.1 Extraction yield

The extraction yield of the active components from plant materials is well-known to be affected by the ratio of water to raw material, which is an important factor. Also, the polarity of the extractant play a key role in increasing the recovery of phenolic and flavonoid compounds [29]. In this work, the experiments were designed to evaluate the impact of extraction solvents on the response variables: extraction yield, TPC and TFC. The selected solvents were 80% ethanol, 80% methanol and 80% acetone and their polarity was in the order 80% methanol > 80% ethanol > 80% acetone. The obtained results presented in Table 1 indicated that polar protic solvents gave better extraction yields and among all used solvents the hydro-ethanol achieved significantly higher extraction yield, and this may tell us that 80% ethanol is a suitable solvent for optimizing extraction yield from *O. stricta* fruit. High extraction yield of hydro-alcohol solvents especially (20:80) hydro-ethanol can be attributed to their capability to dissolve polar along with non-polar molecules [30]. Indeed, the polarity of ethanol system is more consistent for extraction of polar components like, phospholipids, polysaccharides and lipoproteins, which may be the most dominant components of the *O. stricta* fruit material additionally to flavonoid and betacyanin glycosides like isorhamnetein-3-O-rutinoside, betanin, isobetanin and betanidin [5, 31–33]. On the other side, acetone or its combinations with water can be considered as common extractant for tannins and proanthocyanidins [7, 34, 35]. Brglez Mojzer et al. have announced that aqueous acetone is a suitable extractant for flavanols [36].

It is very clear from our experimentation that 80% acetone as extractant system is particularly a good and suitable solvent for recovery of the antioxidant phenolic constituents from the plant material, while 80% ethanol is a suitable solvent for increasing extraction yield as a whole. This undoubtedly proves that selection of proper extraction solvent depends on the type and polarity of the plant material constituents [30–32, 37, 38].

3.2 TPC and TFC

Polyphenols are natural product molecules that are present in plants with different structures and chemical nature and result in mutability of the physico-chemical properties effecting their extraction [39]. It is also known that the antioxidant behavior of fruits is linked to the total polyphenols content which is due to their capacity to block free radicals. The physico-chemical characteristics of the polyphenols, the presence of other interfering chemicals and the nature of solvent can affect their extraction.

Table 1 presents the TPC and TFC of the extracts measured using the Folin Ciocalteau method. The data indicated that 80% acetone was the most effective solvent with a TPC of 29.223 µg GAE/mg dry weight extract whereas 80% methanol and 80% ethanol were the least effective for phenols extraction (17.511 and 16.349 µg GAE/mg) respectively, ($p > 0.05$). It was seen that %80 acetone had enough potential for maximum extraction of *O. stricta* polyphenols.

It was observed that the impact of solvents on TFC is like that on TPC. Indeed, the ranking of increasing TFC was 80% acetone < 80% ethanol and 80% methanol ($p > 0.05$). The highest TFC was obtained in 80% acetone (6.016 µg QE/mg) followed by 80% methanol and 80% ethanol (4.825 and 4.905 µg QE/mg) respectively ($p > 0.05$).

As it can be noticed, 80% acetone solvent, which has the least polarity among the used solvents results in higher extraction percentage of TPC and TFC. This may be attributed to the polarity properties of lipophilic polyphenols and flavonoids like isoflavones, flavanones, methylated flavones, and flavonols which are usually more dissoluble in less polar organic solvents [40].

Our data is in contradiction with Cha et al. findings who observed that the decreasing order of TPC and TFC in Korean *Opuntia humifusa* fruit was 80% ethanol > 80% methanol and 80% acetone ($p > 0.05$) whereas they are in

Table 1 Extraction yield, TPC and TFC of *Opuntia stricta* extracts

Extract	80% acetone	80% methanol	80% ethanol
Color and nature	Orange-red solid	Red solid	Red wine solid
Extraction yield (% w/w)	4.67 ± 0.18^{c}	40.92 ± 0.36^{b}	57.69 ± 0.22^{a}
TPC (µg GAE/g)	29.223 ± 1.894^{a}	17.511 ± 1.737^{b}	16.349 ± 1.719^{b}
TFC (µg QE/g)	6.016 ± 0.069^{a}	4.825 ± 0.069^{b}	4.905 ± 0.119^{b}

Values are mean of three replicates ± standard deviation (n = 3)

Different letters in the same row indicate a significant difference according to Tukey test ($p < 0.05$)

agreement with works of Do et al. and Xiong et al. where the acetone (70–80%) had the larger quantity of TPC and TFC in *Osmanthus fragrans*' seed and *Limnophila aromatica* compared to (70–80%) methanol and ethanol extracts [31, 41, 42]. Although alcoholic aqueous mixtures have been confirmed to be very effective for the extraction of high polyphenols and flavonoids, some recent studies proved that different combinations of acetone and water (50–80%) exhibited the highest values of TPC and/or TFC sometimes without any significance difference with their homologous alcoholic water mixtures [42–48].

3.3 Antioxidant activity

The antioxidant potential analysis can be performed with different methods; however, each method has its merits and demerits. In our study, *O. stricta* extracts have been subjected to three in vitro chemical assays to evaluate their antioxidant capacities which are DPPH, ABTS and FRAP.

Results, summarized in Table 2, exhibited that the values of all in vitro antioxidant activities vary significantly with the type of solvent ($p < 0.05$) and confirmed that the extracts' antioxidant properties are significantly impacted by the type of extraction solvents. All extracts exhibited excellent antioxidant activities but lower than used standards. In DPPH assay, 80% acetone extract exhibited the best scavenging radical activity with an IC_{50} equal to 0.732 mg/mL pursued by 80% ethanol and 80% methanol extracts (IC_{50} = 1.223 and 1.699 mg/mL) respectively. Similarly, the order of increasing FRAP was 80% acetone > 80% ethanol > 80% methanol with EC_{50} equal to 1.860, 3.837 and 3.208 mg/mL respectively. On another hand, the highest quenching potential against ABTS was noticed for 80% acetone (IC_{50} = 1.793 mg/mL) followed by 80% methanol and finally 80% ethanol extracts (IC_{50} = 3.768 and 4.074 mg/mL) respectively.

Table 2 Antioxidant activities of *Opuntia stricta* extracts

DPPH assay (IC_{50} mg/mL)			
Extract	*80% acetone*	*80% methanol*	*80% ethanol*
	0.732 ± 0.017^{c}	1.699 ± 0.036^{a}	1.223 ± 0.011^{b}
Positive control	Quercetin	Trolox	BHT
	0.006 ± 0.000^{d}	0.010 ± 0.000^{d}	0.026 ± 0.000^{d}
ABTS assay (IC_{50} mg/mL)			
Extract	*80% acetone*	*80% methanol*	*80% ethanol*
	1.793 ± 0.019^{c}	3.768 ± 0.101^{b}	4.074 ± 0.111^{a}
Positive control	Trolox		
	0.040 ± 0.000^{d}		
FRAP (EC_{50} mg/mL)			
Extract	*80% acetone*	*80% methanol*	*80% ethanol*
	1.860 ± 0.018^{c}	3.837 ± 0.083^{a}	3.208 ± 0.078^{b}
Positive control	Trolox		
	0.204 ± 0.000^{d}		

Values are mean of three replicates ± standard deviation (n = 3)

Different letters in the same row indicate a significant difference according to Tukey test ($p < 0.05$)

As it can be observed, the ABTS IC_{50} and FRAP EC_{50} are higher than DPPH IC_{50} which can be explained by the fact that the same antioxidant molecule may act differently in the scavenging of various kinds of radicals especially that in vitro chemical assays had different reaction principles [49].

Our results were in accordance with the findings of Kobus-Cisowska et al. who proclaimed that hydro acetone (acetone: water, 75:25 v/v) was the strongest $DPPH^{\bullet}$ radical and $ABTS^{\bullet+}$ scavengers compared to hydro ethanol and hydro methanol (75:25 v/v) [37] and in excellent agreement with works of Zhao et al. who showed that the greatest $DPPH^{\bullet}$ and $ABTS^{\bullet+}$ scavenging activities and the best reducing power were detected in 80% acetone extract compared to 80% methanol and 80% ethanol extracts [50]. Overall, our results from the three in vitro assays suggested that antioxidant capacities of extracts are strongly reliant on the solvent. This may be associated with the chemical structure of phenolic compounds and the availability of phenolic hydroxyl groups which have the capacity to donate their electron or hydrogen, thereby forming stable end products [37]. Furthermore, the presence of flavonoid glycosides in ethanolic and methanolic deseeded fruit extracts may have contributed to their reduced antioxidant activities. In fact, glycosylated polyphenols have reduced ability as hydrogen donors and are less effective as antioxidants compared to their free aglycone forms [51].

3.4 Pearson's correlation analysis

It is recognized that the plant material antioxidant potential usually appears to correlate with the TPC [52]. In our investigation, a correlation analysis was executed on polyphenol contents (TPC and TFC) and in vitro antioxidant

Table 3 Pearson's correlation test (r-values) between TPC, TFC and antioxidant capacity (DPPH, ABTS and FRAP assays) for *Opuntia stricta* extracts

	TPC	TFC	DPPH	ABTS	FRAP
TPC	1	0.962^{**}	-0.805^{**}	-0.970^{**}	-0.900^{**}
TFC		1	-0.891^{**}	-0.972^{**}	-0.953^{**}
DPPH			1	0.799^{**}	0.978^{**}
ABTS				1	0.902^{**}
FRAP					1

**Correlation is significant at $p < 0.01$

potentials using three assays (DPPH, ABTS and FRAP) as summarized in Table 3. The correlation between TPC and TFC assay was strong ($r = 0.962$ at $p < 0.01$). This illustrates that flavonoids are the dominating phenolic group in *O. stricta* fruit. Some flavonoid glycosides were identified among relevant metabolites in *O. stricta var. dillenii* [6].

TPC and TFC had a negative tight correlation with antioxidant features of the extracts with r-values ranging from − 0.805 to − 0.972 at $p < 0.01$. This strong correlation value proposes that the polyphenols and flavonoids present in our extracts are main antioxidants in *O. stricta* fruit. The negative correlation can be explained by the fact that the lower the IC_{50} or EC_{50} value, the higher the antioxidant capacity inhibition [32]. The smallest correlation was obtained between TPC/DPPH and TFC/DPPH while the correlation between TPC/ABTS and TFC/ABTS was the strongest. Previous studies noticed that the rung of correlation between polyphenols and in vitro antioxidant activities relies on the TPC and the composition of extracts [53]. It was announced that polyphenol and flavonoid contents correlated well with antioxidant potency in *Opuntia* genus [41, 43, 54–57].

All in vitro chemical assays showed great positive correlation ($p < 0.05$) of DPPH/ABTS.

($r = 0.799$), DPPH/FRAP ($r = 0.978$) and ABTS/FRAP ($R = 0.902$) which indicates that these methods had an identical response and can be used without discrimination to assess antioxidant potential in *O. stricta* fruit which is comparable to an earlier report [58].

3.5 Antibacterial activity

The results observed for antibacterial capacity of different *O. stricta* extracts against two gram-negative bacteria (*Escherichia coli*, *Salmonella thyphimurium*) and the two gram-positive bacteria (*Enterococcus feacium and Streptococcus agalactiae*) were summarized in Table 4 as inhibition zones (mm). It was clear that all extracts were active towards the four bacterial strains.

The obtained results showed that 80% acetone and 80% methanol extracts exhibited the largest inhibition zones (11.66 and 11.33 mm respectively, $p > 0.05$) against *Salmonella thyphimurium*. These activities presented approximately more than 67% of ampicillin activity. The 80% acetone extract exhibited the best inhibitory effect on *Escherichia coli* additionally to ampicillin ($p > 0.05$) with an inhibition zone of 11 cm. This value is significantly larger than the inhibition zones caused by water-alcohol extracts ($p < 0.05$). These findings are of great importance especially that the studied gram-negative bacteria can cause serious intestinal diseases. Gram-Positive bacterial strains were also inhibited to varying degrees by *O. stricta* extracts. As it can be seen, the type of extractants has no significant impact on antibacterial activity against *Enterococcus feacium* ($p > 0.05$) although 80% ethanol had the strongest inhibition zone. On the other hand, 80% ethanol and 80% acetone extracts were more active towards *Streptococcus agalactiae* ($p > 0.05$) than 80% methanol extract. Our extracts exhibited less than 30% of ampicillin activity against the gram-positive bacteria.

Overall, gram-negative bacterial strains were inhibited by 80% acetone while gram-positive bacteria were inhibited by 80% ethanol. These findings confirmed that gram-positive microorganisms were more susceptible to hydro-alcoholic extracts than gram-negative ones as announced by Aruwa et al. [51].

The inhibitory effect of plant extracts against bacterial pathogens was usually linked with the phenolic composition which can be explicated by adsorption to cell membranes, interaction with enzymes or deprivation of substrate and metal ions [59]. Many research works had successfully identified flavonoid glycosides and their aglycones in water-alcohol extracts of *Opuntia* fruit and cladodes [51, 58–60]. Moreover, Yeddes et al. had identified Isorhamnetin-3-O-rutinoside as marker flavonoid in *O. stricta* peel methanol extract. The existence of flavonoid derivatives in water-alcohol mixtures could explain their antibacterial activity [5].

Furthermore, the capability of 80% acetone extract to inhibit gram-negative bacteria could be expounded by its high amount of phenolic acids which have been revealed to be more inhibitory and toxic to microorganisms [51]. Indeed, a recent study demonstrated that phenolic acids were the prominent polyphenols of 80% (v/v) acetone extract of *Opuntia robusta* and *Opuntia ficus-barbarica*

Table 4 Antibacterial activity (inhibition zone measured in mm) of *Opuntia stricta* extracts

	80% acetone	80% methanol	80% ethanol	Ampicillin
Escherichia coli	11.00 ± 00^{a}	10.00 ± 00^{b}	9.50 ± 0.50^{b}	10.83 ± 0.29^{a}
Salmonella thyphimurium	11.33 ± 0.29^{bc}	11.66 ± 0.29^{b}	10.16 ± 0.58^{c}	16.67 ± 0.58^{a}
Enterococcus feacium	9.50 ± 0.50^{b}	10.50 ± 0.50^{b}	10.83 ± 0.76^{b}	45.67 ± 0.58^{a}
Streptococcus agalactiae	10.00 ± 00^{bc}	9.33 ± 0.29^{c}	10.50 ± 0.50^{b}	31.67 ± 0.58^{a}

Values are mean of three replicates ± SD (n = 3)

Different letters in the same row indicate a significant difference according to Tukey test ($p < 0.05$)

with high quantities of ferulic acid and p-hydroxy benzoic acid [61].

4 Conclusion

Our study findings proved that extractability of bioactive components has been greatly affected by the type and concentration of solvents. Overall, the highest amounts of polyhenols and flavonoids and the highest antioxidant activities were obtained with the less polar solvent (80% acetone) although it presents the least extraction yield. This could be linked to the type and polarity of extracted compounds which might be most likely phenolic acids. It should be also noted that TPC and TFC were highly significantly correlated with the antioxidant activity (DPPH, ABTS and FRAP assays) which make them TPC and TFC might be the major contributors to antioxidant potential. Besides, *O. stricta* extracts were capable to inhibit gram-negative and gram-positive bacterial strains to varying degrees without any observed correlation between polyphenol contents and antibacterial activity. Although, the gram-positive bacteria were less sensitive to all extracts than the gram-negative bacteria, the 80% acetone extract showed the best inhibitory effect on the gram-negative *Escherichia coli* which was slightly higher than ampicillin ($p > 0.05$) and on the gram-negative *Salmonella thyphimurium* in addition to 80% methanol ($p > 0.05$) with highest zones of inhibition.

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Data availability The manuscript has no associated data.

Declarations

Conflict of interest The author declares that they have no relevant financial or non-financial interests to disclose.

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