NUTRITIONAL COMPOSITION OF THE EDIBLE WILD PLANT *OPUNTIA LITTORALIS* (ENGELM.) IN RELATION TO DIFFERENT SEASONS AND EDAPHIC FACTORS

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Abstract. *Opuntia spp.* (Cactaceae) were used as food resources, folk medicine for centuries for its valuable nutritional properties and health benefits in some diseases, specifically diabetes, obesity and cardiovascular diseases. This study aimed to investigate the impact of environmental factors on the qualitative and quantitative nutritional composition of the plant. Physical and chemical soil analyses were performed using Particle Size Analysis, Inductively Coupled Argon Plasma, Flame Photometer and titration methods. The quantitative nutritional assessments for each cladode and fruit were performed using standard Association of Official Analytical Chemists methods. While determinations of amino acids, lipids, sugars have been studied using Amino Acid Analyzer, GC\MS and TLC; respectively. Seasonal variations in ash, crude fiber, carbohydrate, nitrogen, protein and lipid were observed to adapt the changes in climate. Cladodes and fruits contained 17 and 16 protein amino acids, respectively; the major was glutamic acid in both. The GC-MS chromatogram of the petroleum ether extract of the cladode showed the existence of 26 compounds dominated by Undecan and 34 compounds in fruit dominated by linoleic acid. Meanwhile, the TLC sugar profile revealed the presence of 8 free and 6 combined sugars in cladode, 9 free and 5 combined sugars in fruit.
Keywords: *Cactaceae, nutritional value, seasonal variations, primary metabolites, soil, energy value*

Introduction

The western Mediterranean desert of Egypt, as extensively as the whole Egyptian deserts, is characterized by high diversity and abundance of numerous wild plant species and varying climatic and edaphic conditions, which leads to accumulation of high concentrations of useful plant metabolites (Hendawy, et al., 2020; Abdel-Rahman and

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Migahid, 2019). The impact of climatic and other environmental stimuli on the nutrient contents and plant growth have been studied in many previous studies. Crosby, et al. (2008) claimed that the nutritional content of plants is related to many variables, including soil conditions, environment and plant physiological status. Climate change has an impact on the accumulation of metabolites and proteins in plants; plants that suffer from certain types of stress when developing tend to accumulate more nutrients that are valuable to humans relative to those growing under less severe conditions (Ebifa-Othieno, et al., 2020). The Mediterranean coastal basin of Egypt has a warm coastal desert climate (Meigs, 1973) with the warmest summer month having an average temperature of less than 30 °C, and the coldest winter month with an average temperature of above 10 °C, even though occasional short rainstorms occur in winter and autumn (Galal, et al., 2019; UNESCO, 1977). *Opuntia* are xerophyte plants widely named as cactus pear or prickly pear and produce edible fruits and stems or cladodes (Galal, et al., 2019). *Opuntia* is a genus that includes 188 wild species and numerous cultivars; belonging to subfamily Opuntiodeae among the Cactaceae family (Palacios and Valdivia, 2020). *Opuntia ficus-indica* were clarified for their proximate composition of fatty acid, inorganic elements, sugars, and polyphenol (Albergamo et al., 2022). The geographical distribution of the genus covers different ecosystems from sea level to 3400 a. l. m. Moreover, the most widespread habitat for *Opuntia* is in arid, semi-arid and deciduous forests and has been further introduced in the Mediterranean basin, Africa, Asia and Oceania. (Arakaki, et al., 2011). *Opuntia* has a significant degree of ecological adaptation owing to genetic variation and is distributed in nearly all climatic conditions (Bakar, et al., 2020). As nutrition is the most basic human need for development, productivity and mental health, *Opuntia* plants are used as human food and as folk medicines for their health benefits in chronic diseases such as cardiovascular disease, diabetes, obesity and cancer (Chougui, et al., 2013). *Opuntia littoralis* is predominantly grown as irregular clusters on sandy or rocky soils and usually observed as dense clusters spanning several meters (Galal, et al., 2017). Abd El-Moaty, et al., 2020 stated that *Opuntia littoralis'* fruit had strong antidiabetic and antimicrobial activity, as cladodes, against certain bacteria and fungi strains due to the existence of several active components in both. Consequently, no previous studies have been reported on its nutritional content, hence why this study aimed to investigate the proximate nutritional composition of *Opuntia littoralis* growing on the western Mediterranean coast of Egypt and the effect of seasonal environmental variations on it.

Material and methods

Climate of the study area

The study was conducted at Wadi Maged region -25 km to the west of Mersa-Matrouh city and south of Zawyat Umm El-Rakham area- (N 31° 16' 55", E 027° 05' 11", Elevation 2M) on the Northwestern Mediterranean coast of Egypt. The climate of Matrouh is classified as Arid Mediterranean, which is characterized by a long, warm, dry summer and short, cool, rainy winter. Monthly temperatures typically ranged from 14.4 °C to 26.8 °C; August is the warmest month with the maximum average temperature of 29.5 °C, while January is the coolest with a minimum average temperature of 8.7 °C (DRC Staff, 2015). The lowest and the highest relative humidity varies between 66 to 75% in April and July, respectively. The average annual rainfall ranged from 100 to 190 mm (DRC Staff, 2015). Notably in winter, Matrouh receives significant amounts of rainfall; the rainiest are December and January, in summer no or

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few drops of rain are recorded, while occasionally heavy rains can occur in autumn and only about 10% falls during spring (El-Midany, et al., 2019). The main source of irrigation water in the Northwestern Mediterranean coastal zone is rainfall.

Determination of soil properties

Two depths of soils (0-20 and 20-40 cm) supporting plant samples were air-dried and grounded to pass a 2-mm sieve. Soil samples were used for further physical and chemical analysis.

Soil texture and water content

Analysis of soil texture was measured using Particle Size Analysis (PSA) (Gee and Bauder, 1986). The soil water content was determined for the two depths in summer and winter (Sparks, et al., 2020).

Chemical analysis

For chemical analysis, soil:water extract (1:5 *w/v*) was prepared (Harris, 1998) for the following analysis. Soil pH was determined using pH meter (3510, Jenway, UK), while EC was measured using an electrical conductivity meter (Orion 150A+, Thermo Electron Corporation, USA). Potassium and sodium content were determined using flame photometer [7, Jenway, UK] (Jankowski and Freiser, 1961), while calcium and magnesium were evaluated by versine titration method (Estefan et al., 2013). Carbonates and bicarbonates were determined by titration against 0.1 N HCl using phenolphthalein and methyl orange as an indicator. Sulphates were determined by precipitation as barium sulphate using barium chloride in slightly acidic media. Due to fine particles of barium sulphate turbidity formed is proportional to the amount of sulphate in the sample, a photometric reading [Unicam UV 300, Thermo Spectronic, USA] enables the sulphate concentration to be accurately determined (Tandon, 1991). Chloride was determined by titration according to the method described by Estefan et al. (2013).

Heavy metals and trace elements analysis

Soil samples were extracted according to the method described by Soltanpour and Schwab (1977) using NH_4HCO_3/DTPA solution to determine the available heavy metals (Al, Co, Cr, Mo and V), trace elements (Fe, Mn, Cu, Ni and Zn) and phosphorus (P^+) using Inductively Coupled Argon Plasma (iCAP 6500 Duo), Thermo Scientific, England, 1000 mg L^{-1} multi-element. A Certified standard solution, Merck, Germany, was used as a stock solution for instrument standardization (Allen, 1989).

Plant sampling, proximate nutritional composition analysis

Opuntia littoralis was scientifically identified at the herbarium of the Agricultural Museum, Giza (CAIM). The fresh fruits and cladodes were collected seasonally (fruits were not found in spring), then transferred to the laboratory, air-dried at oven 45 °C till constant weight, ground to fine powder, and kept to be used for different plant analysis. Moisture content, ash, organic matter, lipid content and crude fiber analysis were carried out according to the standard procedures of the Association of Official Analytical Chemists (AOAC, 2000). The Kjeldahl method was used to determine crude protein by method number 978.04 (AOAC, 2000). Carbohydrate content was determined by dissolving one

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gram of plant powder in 2-5 ml of 2 M HCl in a sealed tube, then heating it at 100 °C for a period of 5-6 h (Chaplin and Kennedy, 1994). Then the total carbohydrates were estimated using the general phenol-sulfuric acid assay using the method described by Chaplin and Kennedy (1994). All the values were calculated as percentage of the analyzed sample.

Determination of energy value

The energy value of fruits and cladodes of the plant was calculated using the following formula (Crisan and Sands, 1978; Ramchoun et al., 2017)

$$\text{Energy value (kcal/100 g)} = (2.62 \times \%\text{protein}) + (8.37 \times \%\text{fat}) + (4.2 \times \%\text{carbohydrate})$$

The results were expressed in kilocalories.

Qualitative analysis

Investigation of protein-amino acids was achieved according to Pellet and Young (1980) and Cohen et al. (1989) by using amino acid analyzer SYKAM system High-Performance Analyzer with the following parameters: Column: Na High-Performance column (150*4.6) LC AKO6 Na -24050313, Injected volume: 0.1 ml, Flow Rate: 0.45, Detection: 440 + 570 nm, Temperature: 57-74, Retention time and separated area were obtained using Hewlett Packard 3390 recording integrator. However, qualitative determination of free and combined sugars was carried out using TLC by silica gel plates following the method of Ribeiro et al. (2010), using high-purity reference sugars from Sigma-Aldrich: galactose, xylose, arabinose, glucose, fructose, dextrose, sorbitol, glucuronic acid, mannose and sucrose. The GC/MS analysis to determine the lipid content was performed using a Thermo Scientific, Trace GC Ultra/ISQ Single Quadrupole MS, TG-5MS fused silica capillary column (30 m, 250 mm, 0.25 mm film thickness), an electron ionization system with ionization energy of 70 eV, helium gas as the carrier gas at a constant flow rate of 1 ml/min. The identification of the compounds was performed based on the comparison of their relative retention time and mass spectra with those of the NIST and WILLY library data of the GC/MS system.

Statistical analysis

All chemical analysis was performed in triplicate with blank samples for quality control. One-way analysis of variance (ANOVA) was used to assess the significance of seasonal variations of nutritional composition using SPSS, 2006 software (SPSS Inc., Chicago, Ill., USA).

Results and discussion

Soil properties

Soil texture and moisture content are fundamental features for the natural ecosystems and relate to various hydrological and ecological functions in different soil layers (Zhang et al., 2019).

The results in *Table 1* showed climate changes the availability of soil moisture; it reached its maximum during winter coinciding with winter rains and its minimum in summer due to high temperature, drought, relative humidity and high rate of evaporation.

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There was a gradual increase in soil moisture content with such an increase in soil depth attributed to the exposure of the upper layers of desert soil to extreme evaporation, other than that, lower layers have been protected. The desert soil beyond a certain depth has a continuously moist layer to provide deep roots with the water needed (Gao et al., 2014). The data in *Table 1* showed that the texture of the soil supporting *O. littoralis* at Wadi Maged is sandy loam; the soil is alkaline composed of calcium bicarbonate as a major component (*Table 2*), this result is consistent with the result of El-Nady and Shoman (2017) that Wadi Maged soils are moderate to strongly calcareous. Which is confirmed by the previous study by Galal et al. (2017) which reported that; *Opuntia littoralis* cladodes grown in Wadi Maged contain significant quantities of calcium oxalate crystals as druses that are often correlated with an increase in soil calcium accumulation. The analysis of available heavy metals and phosphorus in the soil samples at the two depths (0-20 and 20-40) are shown in *Table 3*. It was found that Fe had the highest concentration (3.41 and 3.35 mg kg-1) followed by Mn (3.09 and 3.092 mg kg-1) in the surface and bottom layers, respectively. Heavy metals exhibit a range of soil characteristics, though plant uptake was comparatively low compared to overall soil intake from different disperse and agricultural sources (Nicholson and Chambers, 2008). Fe and Mn compounds in soil play an important role in restricting the transport of inorganic pollutants in groundwater systems (Stipp et al., 2002) as well as for the purification of soil particles from heavy metals (Gasparatos, 2013). Since Fe and Mn oxides are capable of binding metals, they may be appropriate for the treatment of soils contaminated with toxic metals (Puschenreiter, et al., 2005; Gasparatos, 2013).

Table 1. *Particle size distribution analysis and mean values of moisture content of soil supporting O. littoralis in Wadi Maged, Mattrouh*

Soil depth (cm)	Soil texture	Particle size distribution analysis of soil (%)				Soil moisture content (%)	
		Coarse sand	Fine sand	Silt	Clay	Winter	Summer
0 – 20	Sandy loam	46.75	19.2	20.18	13.88	22.12 ± 0.63	1.83 ± 0.15
20 – 40	Sandy loam	55.07	18.73	13.83	12.38	23.66 ± 0.18	2.13 ± 0.65

Values are expressed as mean of three replicates ± standard error

Table 2. *Chemical analysis of soil supporting O. littoralis*

Soil depth (cm)	pH	E.C (dS m^{-1})	Analysis of soil saturation extract							
			Soluble cations (meq 100 g^{-1})				Soluble anions (meq 100 g^{-1})			
			Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	SO_4^{--}	Cl^-
0-20	8 ± 0.08	0.16 ± 0.85	0.15 ± 0.03	0.05 ± 0.0	0.94 ± 0.06	0.52 ± 0.02	N.D	0.67 ± 0.04	0.55 ± 0.01	0.36 ± 0.02
20-40	8.7 ± 0.14	0.15 ± 0.78	0.13 ± 0.0	0.04 ± 0.002	1.12 ± 0.06	0.40 ± 0.02	N.D	0.92 ± 0.04	0.45 ± 0.001	0.24 ± 0.03

Values are expressed as mean of three replicates ± standard error

Nutritional composition

Opuntia spp. has a high nutritional value owing to its mineral, protein, dietary fiber, and phytochemical contents (Del Socorro et al., 2017). Physiological responses of plants have been significantly threatened by climate change as the probability of suffering from different plant stress has increased owing to environmental extremities

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and climate variability, the seasonal variations in the proximate composition of *Opuntia littorallis* cladodes and fruits are summarized in *Table 4*. The main constituents of cladodes and fruits are carbohydrates (in summer 24.1- 28.4%, respectively %), followed by ash (in spring and summer 12.0- 7.6%, respectively), fibers (in spring and summer 9.4- 6.8%, respectively), proteins (8.9- 5.1%, respectively) and lipids (in autumn 1.8- 4.0%, respectively).

Ash, organic matter and crude fiber content

Ash content is the index of mineral contents in plants such as calcium, sodium, potassium, nickel and zinc. The total ash content of *Opuntia littoralis* reached its maximum value (12.09%) for cladodes during spring, and (7.60%) for fruits in summer which showed that the cladodes were rich in minerals, while the organic matter reached its maximum value (88.72%) and (93.72%) for cladodes and fruits, respectively during autumn (*Table 4*). According to Michael and David (2002), ash content is vital in determining the nutritive value of foods by evaluating the quality of plant grading and providing an idea of the amount of minerals found in the plant. It is well known that *Opuntia* cladodes are a good source of dietary fibers (Uebelhack, et al., 2014) which may help in reducing body weight by binding to dietary fat and increasing its excretion which may explain why cladodes are considered as hypolipidemic and are also found to promote digestion and absorption processes in the small intestine (Díaz, et al., 2017). The percentage of pharmacopeial constants increased as a consequent increase in overall ion accumulation due to an increase in soil moisture stress (Agboola and Adejumo, 2013).

Table 3. *Heavy metals nitrogen and phosphorus analysis of the soil supporting O. littorallis grown in Wadi Maged, Mattrouh*

Metal (mg kg^{-1})	**Soil depth (cm)**	
	0-20	**20-40**
Al (Aluminum)	0.42 ± 0.01	0.32 ± 0.02
Ba (Barium)	0.003 ± 0.00	0.28 ± 0.09
Cd (Cadmium)	0.01 ± 0.00	0.01 ± 0.00
Co (Cobalt)	0.03 ± 0.00	0.08 ± 0.04
Cr (Chromium)	0.04 ± 0.00	0.03 ± 0.00
Cu (copper)	0.56 ± 0.01	0.44 ± 0.04
Fe (Iron)	3.41 ± 0.34	3.35 ± 0.13
Mn (Manganese)	3.09 ± 0.09	3.09 ± 0.05
Mo (Molybdenum)	< 0.002	< 0.002
Ni (Nickel)	0.07 ± 0.01	0.08 ± 0.00
Pb (Lead)	0.28 ± 0.00	0.27 ± 0.01
Sr (Strontium)	0.73 ± 0.03	0.78 ± 0.00
V (Vanadium)	0.16 ± 0.03	0.17 ± 0.03
Zn (Zinc)	0.85 ± 0.05	0.86 ± 0.00
P (Phosphorus)	0.01 ± 0.00	0.02 ± 0.00
N (Nitrogen)	23.95 ± 0.15	35.30 ± 0.40

Values are expressed as mean of three replicates ± standard error

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Table 4. *The average seasonal variations of proximate composition of Opuntia littorallis*

Variable	Season	Cladode	Fruit	Variable	Season	Cladode	Fruit
Total ash (%)	Autumn	11.28[c] ± 0.21	6.28[c] ± 0.03	Total nitrogen (%)	Autumn	0.76[c] ± 0.02	0.75[b] ± 0.01
	Winter	11.64[b] ± 0.29	6.99[b] ± 0.08		Winter	1.42[a] ± 0.11	0.82[a] ± 0.03
	Spring	12.09[a] ± 0.07	--		Spring	1.24[b] ± 0.04	--
	Summer	11.55[c] ± 0.23	7.60 [a] ± 0.30		Summer	0.4[d] ± 0.003	0.44[c] ± 0.004
Organic matter (%)	Autumn	88.72[c] ± 0.21	93.72[a] ± 0.03	Protein content (%)	Autumn	4.77[c] ± 0.15	4.69[b] ± 0.07
	Winter	88.36[b] ± 0.29	93.00[b] ± 0.08		Winter	8.90[a] ± 0.70	5.15[a] ± 0.23
	Spring	87.91[a] ± 0.07	--		Spring	7.73[b] ± 0.23	--
	Summer	88.45[c] ± 0.23	92.40[b] ± 0.30		Summer	2.6[d] ± 0.02	2.77[c] ± 0.03
Crude fiber (%)	Autumn	6.83[b] ± 0.189	5.78[b] ± 0.206	Total lipids (%)	Autumn	1.86[a] ± 0.03	4.09[a] ± 0.20
	Winter	7.23[b] ± 0.403	4.90[b] ± 0.216		Winter	1.69[b] ± 0.05	3.2[c] ± 0.03
	Spring	9.48[a] ± 0.403	--		Spring	1.59[c] ± 0.07	--
	Summer	6.91[b] ± 0.294	6.90[a] ± 0.374		Summer	1.46[d] ± 0.02	3.6[b] ± 0.01
Total carbohydrates (%)	Autumn	23.23[c] ± 0.369	21.55[b] ± 0.526	Energy value (kcal/100 g)	Autumn	123.93[a] ± 2.016	135.38[b] ± 1.115
	Winter	15.45[a] ± 0.493	9.63[c] ± 0.419		Winter	99.10[c] ± 0.982	78.95[c] ± 0.982
	Spring	12.23[b] ± 0.240	--		Spring	82.13[d] ± 0.726	--
	Summer	24.18[c] ± 0.793	28.40[a] ± 0.963		Summer	119.58[b] ± 1.127	155.80[a] ± 0.245

Carbohydrate content

The total carbohydrate content of *Opuntia littoralis* reached its maximum values (24.15 and 28.41%) for cladodes and fruits, respectively during summer, while the minimum was 12.22% for cladodes and 9.63% for fruits in spring and winter. Carbohydrates provide energy to cells in the body, the brain depends only on carbohydrates as a source of energy (Ebifa-Othieno, et al., 2020). Excess water in the soil in winter can also result in a reduction of photosynthesis (Mielke and Schaffer, 2010). These results are also consistent with Xu and Zhou (2011) who stated that excessive moisture levels, photosynthesis and stomatal conductance, as well as carbohydrate content decreased.

Total carbohydrate represents the highest constituent among determined nutritional composition of *Opuntia littorallis* plant as shown in *Table 4*. Large amount of

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carbohydrates is correlated with the high concentration of iron (Fe) and manganese (Mn) in the soil (*Table 3*). Iron is involved in the synthesis of chlorophyll and is essential for maintenance of chloroplast structure and function (Rout and Sa hoo, 2015). Manganese (Mn) also, plays a role in chlorophyll production which is essential in photosystem II (Mousavi et al., 2011).

TLC profile of free and combined sugars

Carbohydrates and their derivatives in living cells provide flexibility and structure, supply energy, and act as regulators and substrates for several specific biochemical processes (Bokov et al., 2017). Analysis of free and combined sugars of the cladodes and fruits using TLC (*Table 5*). Data revealed the presence of eight free sugars (glucose, fructose, xylose, arabinose, galactose, sorbitol, glucuronic acid and mannose) and six combined sugars (glucose, arabinose, galactose, sorbitol, mannose and dextrose) at the cladodes. Meanwhile, the fruits contain nine free sugars (glucose, fructose, xylose, arabinose, galactose, sorbitol, gluconic acid, mannose and dextrose) and five combined sugars (glucose, arabinose, galactose, sorbitol and mannose).

Table 5. *Free and combined sugars of Opuntia littorallis cladodes and fruits using TLC*

Sugar	Free sugars		Combined sugars	
	Cladodes	**Fruits**	**Cladodes**	**Fruits**
Glucose	+ ve	+ ve	+ ve	+ ve
Fructose	+ ve	+ ve	-ve	-ve
Sucrose	-ve	-ve	-ve	-ve
Xylose	+ ve	+ ve	-ve	-ve
Arabinose	+ ve	+ ve	+ ve	+ ve
Galactose	+ ve	+ ve	+ ve	+ ve
Sorbitol	+ ve	+ ve	+ ve	+ ve
Gluconic acid	+ ve	+ ve	-ve	-ve
Mannose	+ ve	+ ve	+ ve	+ ve
Dextrose	-ve	+ ve	+ ve	-ve

Nitrogen and protein content

The total nitrogen content reached its maximum values (1.42 and 0.82%) for cladodes and fruits, respectively during winter, while the minimum (0.41 and 0.44%) for cladodes and fruits in summer (*Table 4*). So, the percentage of total protein reached its maximum values 8.90% and 5.15% for cladodes and fruits, respectively in winter, while reached its minimum values 2.61% and 2.77% during summer for cladodes and fruits, respectively. The decrease of total nitrogen and protein content in summer may be attributed to the decrease of water resources of the soil, which was related to the accumulation of some amino acids (e.g. proline) that may participate in adjusting cell osmoregulation. Our results are in accordance with a previous study by Silva et al. (2020) which stated that water stress in summer led to large decreases in protein percentage of Wheat grains. The obtained results also agree with those of Cauquil et al. (2017); who reported a decrease in the level of protein with a progressive increase in the accumulation of amino acids in the tissue, which was

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recorded in many plants during water stress. The protein promotes the formation of hormones that control many body functions such as growth, repair and maintenance of body protein (Mau et al., 1999).

Investigation of protein amino acids

Data on protein amino acid analysis of the cladodes and fruits are represented in *Figures 1* and *2*, respectively. The obtained data of protein amino acid analysis showed that 17 and 16 protein amino acids with different concentration ranges were detected in the cladodes and fruits of *Opuntia littoralis* respectively (*Figs. 1* and *2*). It can be concluded that the major protein amino acids were glutamic and aspartic acids in cladodes and fruits. On the other hand, methionine (0.09 and 0.08 mg g-1) was the minor protein amino acid in cladodes and fruits, respectively. Aspartic acid is a non-essential amino acid, but it has an important role in purine, pyrimidine, and asparagine and inositol synthesis. Aspartic acid has been used as mineral salts such as magnesium aspartate or potassium aspartate to improve energy production in exercising muscles (Akram et al., 2011). Quantitative and qualitative changes in the synthesis of plant proteins may be due to a response to water deficiency (Pessarakali, 1995). Different amino acids are used in the human body as precursors for the synthesis of proteins and other nitrogen-containing compounds. Of the 20 amino acids commonly required by the body for protein synthesis and other compounds, 9 amino acids are essential in the diet of an adult man (Murray et al., 2006). It is also reported that, if one of the essential amino acids, which cannot be synthesized in the body, is lacking or inadequate, it will not be possible to maintain nitrogen balance since there will not be enough of that amino acid for protein synthesis regardless of the total intake of protein (Murray et al., 2006). Moreover, one of the important amino acids is proline with a concentration of 3.59 and 4.08 mg g -1 in the cladodes and fruits, respectively. The accumulation of proline due to increased synthesis and decreased degradation under a variety of stress conditions such as salt and drought has been documented in many plant species (Kishor et al., 2005); it is thought to protect plants during drought condition (Chorkaew et al., 2017). Proline seems to have diverse roles under osmotic stress conditions, such as stabilization of proteins, membranes and sub-cellular structures and protecting cellular functions by scavenging reactive oxygen species (Szabados and Savouré, 2010). In addition, the increase in proline and glutamic content may be due to the increase in soil salinity according to Ali and Sawaf (1992) who reported that salinity inhibits the transmission reaction. Moreover, glutamic acid can be accumulated and transformed into other nitrogenous compounds such as proline. In general, drought causes an increase in amino acids in plants (Chorkaew et al., 2017).

Lipid content

The data presented in *Table 4* showed that the percentages of total Lipid content of *Opuntia littoralis* reached its maximum values (1.86 and 4.09%) for cladodes and fruits, respectively during autumn, while its minimum was 1.46% for cladodes in summer and 3.21% for fruits in winter. Water deficit in summer results in metabolic changes in plants. Among them are the stimulation of lipolytic, peroxidative activities and the inhibition of lipid biosynthesis which lowers the content of membrane lipids (Labusch et al., 2013). Drought affects the accumulation of oil in the seeds (Martínez Ballesta et al., 2013). Drought also reduces the accumulation of lipids in peas, sunflower, maize,

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lupine, and wheat (Silva, et al., 2020). The highest percentage of total lipids in autumn and winter may be attributed to the enhancement in the metabolic rate of the plant, which leads to an increase in carbohydrate content, which converts to lipid by oxidation reaction (Stocker, 1960).

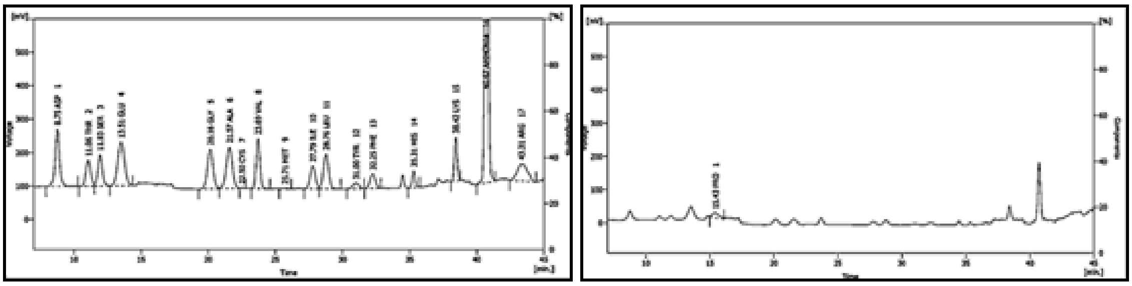

Figure 1. *The separated hydrolyzed protein amino acids and proline of O. littoralis cladodes*

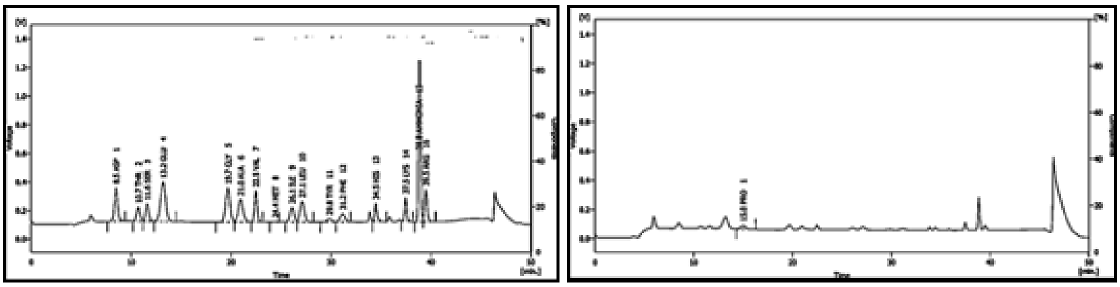

Figure 2. *The separated hydrolyzed protein amino acids and proline of Opuntia littoralis fruits*

GC-MS chromatogram of the petroleum ether extract of the cladodes of *Opuntia littoralis* showed the presence of 26 compounds {series of (C7-C44)}, predominated by Undecane followed by Dodecane (*Fig. 3*). Meanwhile, the chromatogram of the petroleum ether extract of the fruits revealed the presence of 34 compounds predominated by Linoleic acid followed by Palmitic acid with a significant percentage (*Fig. 4*). Several studies have indicated that cactus particularly; fruits, pulp, seed and prickly pear peel were rich in linolenic, oleic and palmitic acids (Soel, et al., 2007). The most important essential fatty acid in human nutrition is linolenic acid. A High amount of omega-6 linoleic acid was reported in cactus pulp and peel; as a precursor of arachidonic acid, linoleic acid has long been accepted as having a hypocholesterolemic effect and inhibitory properties against colon cancer metastatic cells (El-Beltagi, et al., 2019). Linoleic acid also found to prevent cardiovascular diseases (Afifi, et al., 2018). Fatty acids play a natural preventative role in cardiovascular diseases and the improvement of some other health problems (Faremi and Ekanem, 2011). Poly-unsaturated fats promote the reduction of both total and LDL cholesterol and a significant small decrease in HDL cholesterol (Chougui, et al., 2013). The fatty acid composition of the cactus pear fruits is similar to grape and rapeseed (Özcan and Al-Juhaimi, 2011). *Opuntia ficus indica* seed exhibits a higher proportion of polyunsaturated fats (linoleic acid), compared to certain conventional edible vegetable oils (Kolniak-Ostek et al., 2020). This characteristic demonstrates that Opuntia fruits may be a remarkable natural source of edible oil with high amounts of healthy fatty acids.

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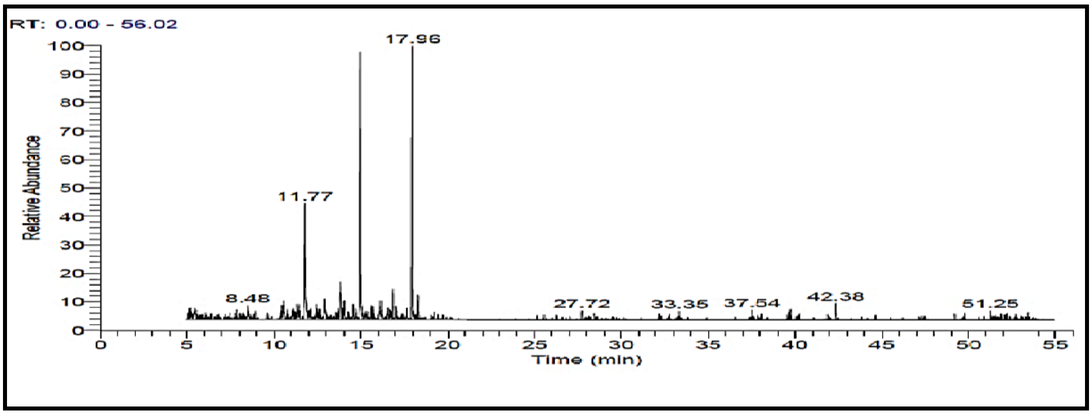

Figure 3. *GC -MS chromatogram of the petroleum ether extract of cladodes*

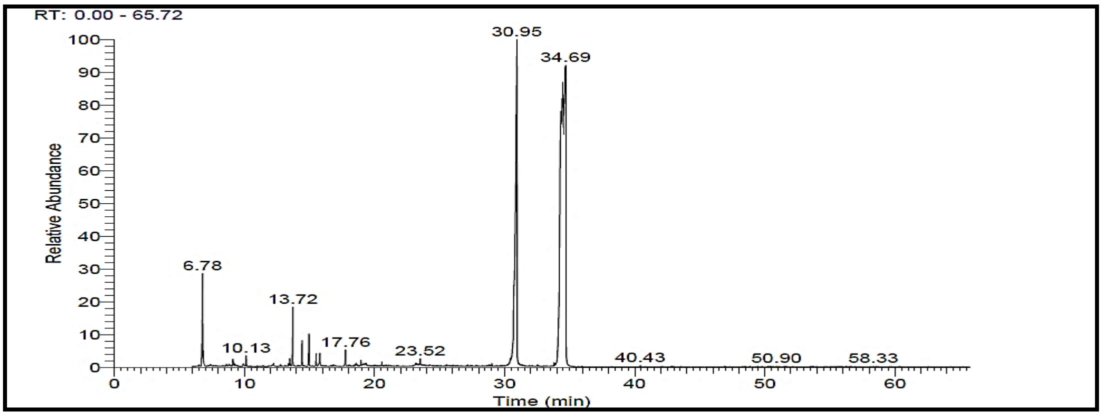

Figure 4. *GC -MS chromatogram of the petroleum ether extract of the fruit*

Energy value

Opuntia fruits ripening during the dry season are promising sources of nutrients during the dry season when food supply is inadequate. Energy is an essential demand to maintain the body’s various functions, such as respiration, circulation, physical work, and protein synthesis (Ebifa-Othieno et al., 2020). The data in *Table 4* showed that the ranges for the estimated calorific value of cladodes are 82.1- 123.9 kcal/100 g in spring and autumn, respectively. While in fruits it is 135.3- 155.8 kcal/100 g in autumn and summer, respectively. These results indicate that *Opuntia littoralis* has the potential to contribute significantly to energy needs particularly during the drought period when food is limited.

Conclusion

Opuntia littorallis has a high nutritional value. The main constituent of cladodes and fruits is water followed by carbohydrates, ash, proteins then lipids. The plant adapted to climatic changes at Wadi Maged region by changing its chemical composition to overcome different types of stress. The plant tends to accumulate amino acids especially glutamic, aspartic and proline in summer to overcome the water deficiency. The lipid profile of *Opuntia* fruits may be an interesting natural source of edible oil containing high amounts of healthy fatty acids.

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