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Desert greens: Unveiling the antioxidant power and health benefits of Qatar's locally grown leafy vegetables

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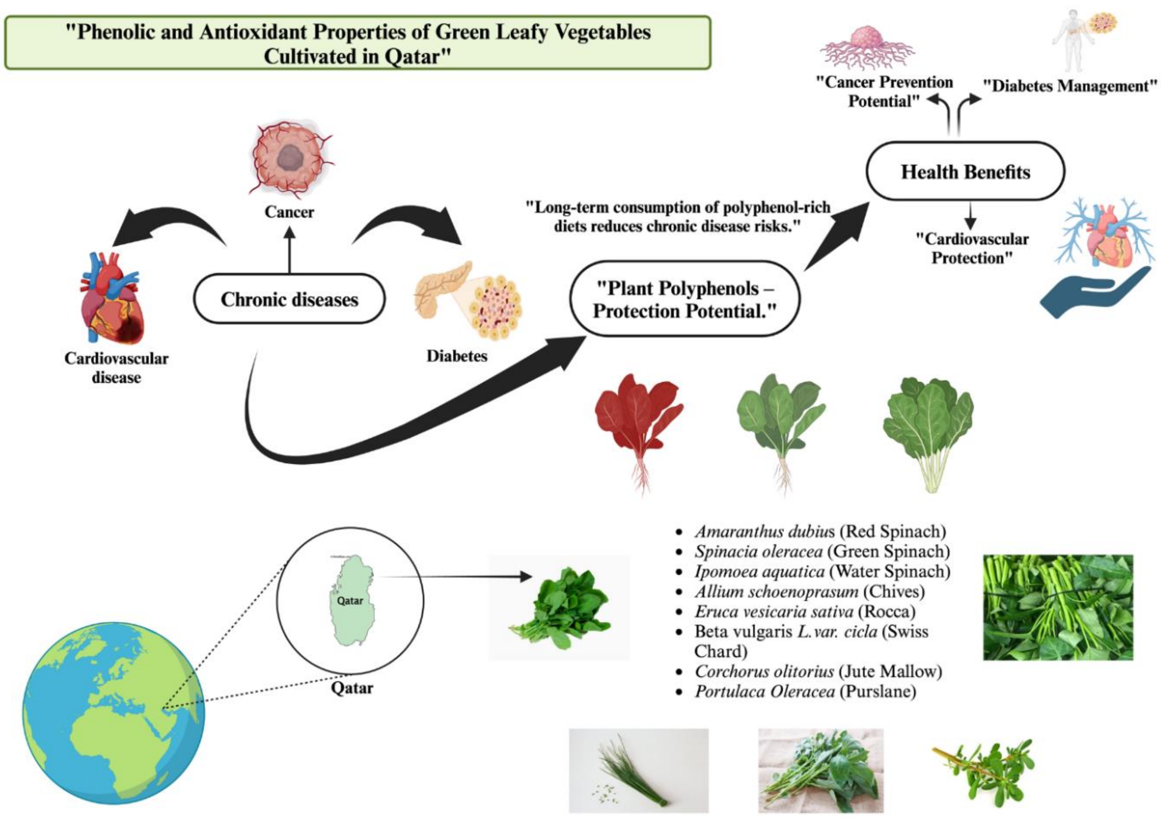
SUMMARY

The long-term consumption of diets rich in plant polyphenols has a high potential to reduce the risk of chronic diseases such as cancer, cardiovascular disease, and diabetes. This study focuses on the phenolic and antioxidant properties of eight green leafy vegetables, red spinach, green spinach, water spinach, chives, rocca, Swiss chard, jute mallow, and purslane, commonly cultivated in Qatar. Antioxidant capacity (AC) was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method. The total phenolic content (TPC) of the samples was quantified using the Folin-Ciocalteu assay. Among all the vegetables, results indicated significant differences among all examined values at level of 5% Jute Mallow exhibited the highest phenolic content at 205.39±11.50 mg GA/100g, followed by Green Spinach at 189.58±10.56 mg GA/100g and Red Spinach at 185.15±2.93 mg GA/100g. Swiss chard exhibited the highest antioxidant activity of 89.26%. This study provides valuable data on these vegetables to positively affect the health and well-being of the population. Intensifying further future investigation to embrace a wider phytochemical profile (e.g., flavonoids, carotenoids, vitamin C), varied antioxidant assays (e.g., FRAP, ABTS), and bioavailability tests would expand the understanding of the studied leafy vegetables health benefits.

Graphical summary



Keywords: *Phenolic compounds; antioxidant potential; green leafy vegetables; well-being; Qatar*

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INTRODUCTION

Green leafy vegetables have long been recognized for their rich nutrient profile, which includes vitamins A, C, and K, as well as various minerals and fiber. The consumption of these vegetables is connected to several health benefits, as well as a lower risk of chronic diseases and general well-being (Morris et al., 2018). Qatar is considered the hottest desert region with a promptly increasing economy in the Arabian Gulf and has shown a change in cultivated practices. The development of green leafy vegetables in Qatar has increased consequences as part of the country's plans to improve food security and condense reliance on introduced food. A study conducted by Elobeid et al. (2021) examined the incidence of Organochlorine Pesticides (OCP) in fruits, vegetables, water, and soil and their revelation to pesticides in Qatar. An alternative study by Alsafran et al. (2021) investigated the bioaccumulation of metalloids in leafy vegetables to deliberate their carcinogenic and non-carcinogenic health hazards. Finally, a study by Huda et al. (2018) aimed to improve vegetable invention in Qatar addressed ideal planting times, compact manufacturing risks, and enhanced water and nutrient use effectiveness.

A number of previous studies have indicated that foods rich in phytochemicals may play a protective role in supporting human health. Likely, health benefits of fruits and vegetables have been partially accredited to their phenolic content. Phenolic composites are a large group of phytochemicals normally originate in vegetables and have established great attention as probable protecting agents contrary to cancer, heart disease, and health-promoting extracts. Furthermore, they play crucial roles in various plant functions and are currently found in a variety of foods and pharmaceuticals (Frond et al., 2019). Considerable attention has been compensated to their effective antioxidant properties in neutralizing Reactive Oxygen Species (ROS) and preventing them from causing oxidative damage (Nurzyńska-Wierdak, 2023). The major phenolic compounds generally found in vegetables include hydroxybenzoic acids, hydroxycinnamic acids (such as caffeic acid, gallic acid, protocatechuic acid, and chlorogenic acid), hydrolyzable tannins (such as pedunculagin, punicalin, punicalagin, and ellagic acid), and flavonoids, including anthocyanins (Pinto et al., 2021). Several research has stated a relationship between polyphenol ingesting and a compact incidence of coronary heart diseases. The mechanisms by which polyphenols may be defensive include antioxidant, anti-platelet, and anti-inflammatory properties, as well as inhibition of low-density lipoprotein (LDL) oxidation. Several studies have reported the antidiabetic effects of polyphenols (Rahman et al., 2021). Polyphenols may affect glycemia through different mechanisms, including inhibition of glucose absorption in the gut or its uptake by peripheral tissues. Polyphenols also play a role in reducing the adverse effects of aging on the nervous system and brain (Pandey and Rizvi, 2009). Although several studies have reported on phenolic compounds in vegetables, none have investigated this association in Qatar.

The antioxidant system of living organisms consists of three important enzymes: peroxidase (POX), Superoxide Dismutase (SOD), and catalase (CAT). SOD (EC 1.15.1.1) increases the transformation of superoxide anions (O_2) into less responsive types, such as H_2O_2 and O_2. This enzyme is originate in a diversity of cellular compartments such as chloroplasts, peroxisomes, cytoplasm, and mitochondria (Zhou et al., 2019). On the other hand, POX, an iron heme protein, supports the breakdown of H_2O_2 into H_2O and O_2. It mainly functions within the cell wall region and helps oxidize phenolic chemicals during lignin production (Bao et al., 2023). Also, CAT oversees the conversion of H_2O_2 into H_2O and O_2. It is mostly set in peroxisomes and mitochondria but is absent in chloroplasts (Guo et al., 2019). Several cellular compartments include other enzymes in addition to these essential antioxidants, which actively maintain redox equilibrium and scavenge reactive oxygen species (ROS) and their by-products. These enzymes include glutathione S-transferases, monodehydroascorbate reductase, dehydroascorbate reductase, glutathione reductase, and alternative oxidases. Therefore, these enzymes are considered components of the antioxidant defense system (Zhou et al., 2019). The inflammation and oxidative stress can arise directly due to an imbalanced dietary pattern categorized by the consumption of high-fat and high-carbohydrate meals. Higher post-meal lipopolysaccharide (LPS) and toll-like receptor-4 (TLR4) levels are closely related to increased levels of inflammatory cytokines, such as interleukin (IL)-6, IL-17, and tumor necrosis factor-alpha (TNF-α), eventually leading to oxidative stress. The role of nutrition in exacerbating or alleviating inflammatory and oxidative stress is of paramount importance (Serafini and Peluso, 2017). Most dietary guidelines emphasize that at least half of each meal consists of fruits and vegetables, with green leafy vegetables (GLVs) as a vital component of a healthy diet. These nutrient-dense diets are rich in minerals, vitamins, dietary fiber, flavonoids, phenolic composites, and carotenoids, all of which contribute to several health benefits (Li et al., 2021). GLVs are valuable in lowering the risk of cardiovascular diseases and cancer. Miller et al. (2017) stated a strong association between increased fruit and vegetable consumption and a reduced risk of stroke. Moreover, GLVs are mainly useful for people with type 2 diabetes because of their high magnesium level, fiber content, and low glycemic index, which can help adjust blood sugar levels. Bondonno et al. (2021) emphasised the cardiovascular benefits of consuming nitrate-rich vegetables, relating them to lower systolic and diastolic blood pressure levels, which helps inclusive cardiovascular health. Furthermore, GLVs display antimicrobial properties, making them valued not only for nutrition but also for extending the shelf life of different foodstuffs.

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The objective of this research was to examine the phenolic compounds, as well as their antioxidant capacity, and prospective health benefits of green leafy vegetables grown in Qatar. This study supports the growth of locally sourced foods that sponsor well-being and health. By investigating the chemical contents of these locally cultivated greens, we can gain a respected understanding of their influence on the health of the Qatari people.

MATERIALS AND METHODS

Sample Extraction and Preparation

In this experiment, eight of different green leafy vegetables, of Qatar orinin were purchased from various local market. The specific species of these vegetables were indicated with scientific, local and common names as follows: *Spinacia oleracea* (Green Cheera - Green Spinach (GS)), *Amaranthus dubius* (red cheera - red spinach (RS)), *Corchorus olitorius* (molokhia - jute mallow (MO)), *Ipomoea aquatica* (water spinach - Kangkong (SP)), *Beta vulgaris* L.var. cicla (silk, - Swiss Chard (SI)), *Portulaca Oleracea* (Barbeer/Bakleh (BR). *Allium schoenoprasum* Purslane ((BA) Bagal - Chives)), and *Eruca vesicaria* (JA) Jarjir, Rocket Leaves/Rocca). Pieces were cut from three distinct areas of each plant and homogenized. For each sample (2.5 g), 100 mL of distilled water was used for extraction under reflux at 95 °C for 30 min. The resulting extracts were then centrifuged at 11,000 × g for 10 min to separate cellular debris.

Estimation of Total Phenolic Compound (TPC)

The total phenolic content (TPC) of the extracts was determined using the Folin-Cicocalteu method previously described by Kwon et al. (2006). In brief, 0.5 mL of the extract was mixed with 1 mL of 95% ethanol, 5.5 mL of distilled water, and 0.5 mL of 50% Folin-Ciocalteu reagent. After allowing the mixture to react for five minutes, 1 mL of 5% sodium carbonate was added to halt the reaction. The absorbance of the mixture was measured at 725 nm using a UV-visible light spectrophotometer (Agilent Model 8453) after a 1-hour dark incubation. Gallic acid was used as a standard, and the results were expressed as mg gallic acid/100 g FW of fresh sample weight.

Antioxidant Activity

The antioxidant capacity (AC) of the extracts was determined using a modified 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method as described by Kwon et al. (2006). A 250 μL aliquot of the sample extract was mixed with 1.25 mL of DPPH solution (60 μL in ethanol) and centrifuged at 5000 g for one minute. The absorbance was measured at 517 nm using an Agilent UV-visible light spectrophotometer, as described previously. The absorbance readings of the sample extracts were compared to a control, which contained 95% ethanol instead of the sample extract.

Statistical Analysis

The data was analyzed using the software R (version 4.4.1). Mainly, descriptive statistics (mean and standard deviation) were applied for total phenolic content (TPC) and antioxidant capacity (AC) in this study among the different leafy vegetables. The ANOVA test at 5% significance was done to examine differences. The Tukey HSD (Honest Significant Difference) post hoc test was then completed to define exact variances among collections.

RESULTS

Total Phenolic Content of Vegetable Leaves

The descriptive analyses showed that among all the green leafy vegetables, Jute Mallow exhibited the highest phenolic content at 205.39±11.50 mg GA/100g, followed by Green Spinach at 189.58±10.56 mg GA/100g and Red Spinach at 185.15±2.93 mg GA/100g, as shown in *Figure 1*. Swiss Chard had a slightly lower but consistent phenolic content of 175.49±3.40 mg GA/100g, whereas Common Purslane had a TPC of 146.10±2.42 mg GA/100g. Chives and Rocca displayed the lowest phenolic content among the vegetables listed, with mean TPC values of 85.09±6.33 and 80.97±3.44 mgGA/100g respectively. The ANOVA test result indicated significant differences among all examined values of TPC for different leafy vegetables at a considerable level of 5% with a p-value of <.001 at a 5% significant level. The Tukey HSD (Honest Significant Difference) post hoc test was performed at a 5% significant level to evaluate the consequence of variances between the mean values of TPC across several natures of leafy vegetables (BA, BR, GS, JA, MO, RS, SI, and SP). The results provide an optical summary of a wider range of variability in TPC values. Substantial differences in TPC levels are obvious between the leafy vegetable groups *Figure 1*. Statistical groupings indicated by letters (a, b, c, d, etc.) represent statistically distinct levels. For instance, the vegetables marked with "a" (MO and RS) have significantly higher TPC than those marked with "d" (BA and BR). Vegetables MO and RS display the highest TPC values, signifying these are richer in phenolic composites, which subsidize antioxidant activity. Vegetables BA and BR demonstrate the lowest TPC values, with no overlay with higher TPC groups, as shown by statistical separation. Vegetables SI and SP show reasonable TPC levels when compared to statistical groupings (e.g., "bc"). Certain vegetables, such as RS and MO, show wider ranges and longer whiskers, representing higher variability in their TPC values. In contrast, JA has a smaller spread, replicating reliable TPC values.

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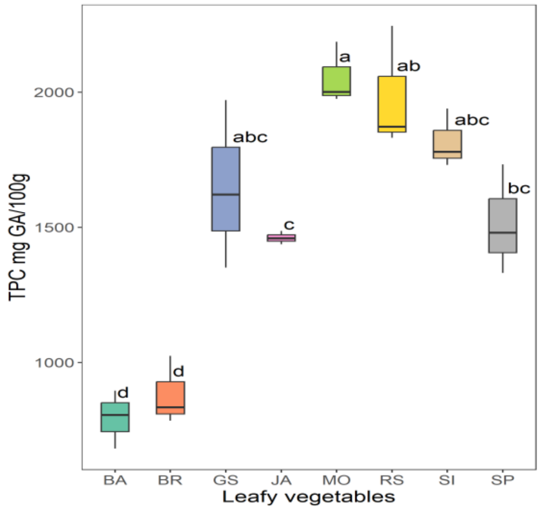
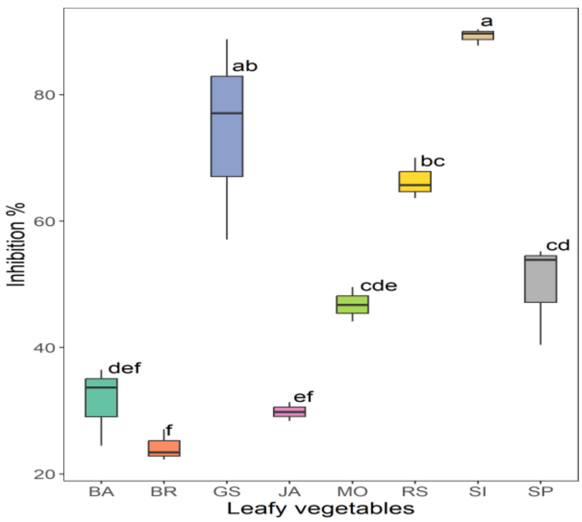
Figure 1. **Total phenolic content of the Qatar-grown leafy vegetables (mg GA/100g FW). Leafy vegetables: Green spinach (GS), Red Spinach (RS), Molokhia (MO), Spinich Kangkong (SP), Silk (SI), Jarjir (JA, Bagal (BA) and Barbeer (BR). Different letters indicate significant differences (p < 0.05)**



Antioxidant Capacity of Vegetables Grown in Qatar

To evaluate the antioxidant activities of Qatar-grown vegetables using the 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) free radical assay, the order of antioxidant capacity, from highest to lowest, was as follows: Swiss chard exhibited the highest antioxidant activity of 89.26%). followed by Green Spinach, with a mean antioxidant activity of 74.29%. Red Spinach showed a moderate antioxidant capacity with a mean of 66.46%, while Jute Mallow demonstrated a slightly lower antioxidant activity, with a mean of 46.81%. Water Spinach had a mean antioxidant activity of 49.83%. Purslane, Chives, and Rocca displayed lower antioxidant activities, with mean values of 29.85%, 31.54%, and 24.26%, respectively. The ANOVA test result indicated significant differences among all examined values of AC for different leafy vegetables at a considerable level of 5% with a p-value of <.001 at a 5% significant level. The Tukey HSD (Honest Significant Difference) post hoc result indicated that SI has the highest inhibition percentage value, which is noticeable as a group "a," signifying a greater antioxidant perspective. BR illustrations the lowest inhibition % grouped as "f.". SP and GS display comparatively high inhibition %, grouped in "ab" and "cd," respectively. MO and RS exhibit reasonable activity, as shown by their overlap with groupings "bc," "cde," or "cd. BA and JA express low inhibition % but are still distinct from BR, which shows the weakest antioxidant potential. Vegetables such as SI have a narrow spread, reflecting consistent inhibition values. GS and SP have a wider range and whiskers, representing variability in inhibition % *Figure 2*.

Figure 2. **Antioxidant capacity of the leafy vegetables using 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) free radical assay. Green spinach (GS), Red Spinach (RS), Molokhia (MO), Spinich Kangkong (SP), Silk (SI), Jarjir (JA, Bagal (BA) and Barbeer (BR). Different letters indicate significant differences (p < 0.05)**



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DISCUSSION

Total phenolic content

Our study examined the Phenolic Composition and Antioxidant Potential to demonstrate the benefits of green leafy vegetables grown in Qatar as healthy vegetables commonly recommended for human consumption. This study encompassed eight different varieties of GLVs. We meticulously examined the total phenolic content (TPC) and antioxidant activity (AC) of these vegetables, shedding light on the variations among different varieties and their responses to Qatar's hot and dry environmental conditions. The results provide intriguing insights into the phenolic composition and antioxidant potential, providing a foundation for understanding the nutritional aspects of locally grown green leafy vegetables and their potential implications for public health and dietary recommendations in Qatar.

In our study, we observed significant variation in polyphenolic content among different green leafy vegetables, including *Spinacia oleracea* (Green Cheera - Green Spinach (GS)), *Amaranthus dubius* (red cheera - red spinach (RS)), *Corchorus olitorius* (molokhia - jute mallow (MO)), *Ipomoea aquatica* (water spinach - Kangkong (SP)), *Beta vulgaris* L.var. cicla (silk, - Swiss Chard (SI)), *Portulaca Oleracea* (Barbeer/Bakleh (BR). *Allium schoenoprasum* Purslane ((BA) Bagal - Chives)), and *Eruca vesicaria* (JA) Jarjir, Rocket Leaves/Rocca). Compared to the previous and conducted studies, the concentration of phenolics in green spinach resulted in this research shown as gallic acid (GA), which was about 189.58 mg GA/100g. This level is lower than 208.8 mg GA/100g testified by Bunea et al. (2008). Besides, the phenolic content in red spinach was 185.15 mg GA/100 g, which is higher than the 133.92 mg GA/g indicated by House et al. (2020). Correspondingly, the study by Bang et al. (2021) revealed that red spinach grown in Qatar has a higher phenolic content (97.8–141.9 mg GA/100 g) compared to our results. These variances can be attributed to differences environmental conditions. Furthermore, the level of phenolic content in jute mallow was 205.39 mg GA/100 g, which is meaningfully higher than the 6.57–11.11 mg GA/100 g indicated by Biswas et al. (2023). Moreover, a study by Hamzah et al. (2013) shows higher of phenolic content of 630.8 mg/100 g for jute mallow, in contrast to the 205 mg/100 g shown in our present study.

The swiss chard examined by Ninfali and Angelino (2013) displayed a phenolic compound of 11.12 mg GA/g; however, Mzoughi et al. (2019) revealed an expressively higher level of 96.58 mg GA/g. In this study, the phenolic content of the swiss chard was higher than both previous outcomes at 175.4950 mg GA/100 g. The TPC concentration in the experimented purslane was 0.32 mg/g in a study done by Erkan (2012) though, the phenolic content in this present study was 146.1033 mg GA/100g, which is greatly higher. This increase may be attributed to the effect of heat on the synthesis or retention of the phenolic compounds. The phenolic content in the ethanolic extract used for chives was determined to be higher (111.28 mg) compared to other extracts (ethyl acetate – 107.68 mg GA/100g and hexane – 102.26 mg GA/100g), compared to the lower phenolic content found in the chives grown in Qatar which was 85.0850 mg GA/100g. The observed variations in the phenolic compound content within the extracts were ascribed to the influence of the organic solvent on the extracted phytochemical compounds (Sinaga et al., 2018). Saadi Abdul-Jabbar (2018) reported that freshly harvested rocket leaves are a substantial source of phenolics (8.00 mg TAE/g extract), however, the phenolic contents decreased with different extracts (alcoholic extract - 5.0 mg TAE/g, Flavonoid extract – 3.3 mg TAE/g, and anthocyanin extract – 1.3 mg TAE/g), on the other hand, the phenolic content was higher (80.9650 TPC mg GA/ 100 g) in the rocket leaves grown in Qatar.

Total Antioxidant Activity

In this comprehensive investigation of the antioxidant potential of various green leafy vegetables grown in Qatar, notable variations were observed. Yong et al. (2017) reported that red spinach exhibited an antioxidant activity of 60.99%, which is lower than 66.45% in the distinct environmental conditions of Qatar. Similarly, Sinaga et al. (2018) indicated that green spinach demonstrated lower antioxidant activity, ranging from 39.5% compared to 24.2%, a remarkably increased value of 74.29% in cultivated green spinach in Qatar. Water spinach demonstrated higher activities between 51.53% and 77.23%, as reported by Fu et al. (2011), compared to a slightly lower value of 49.84% observed in Qatar. Chives showed activities ranging from 61.08% to 78.37% (Alara et al., 2023), yet in Qatar, it displayed a comparatively lower activity of 31.54% (Sinaga et al., 2018).

Alam et al. (2014) reported that rocket leaves, initially showing lower activities between 11% and 17%, displayed an increase of 24.26% in Qatar's challenging climate. Remarkably, swiss chards maintained a consistently high antioxidant activity of 89% in different regions in Italy, highlighting its resilience to diverse environmental conditions Caruso et al. (2019) and Sacan and Yanardag (2010). Roberts and Moreau (2016), and Alara et al. (2023) reported that Jute mallow demonstrated higher activities between 45.07% and 69.85%, with a modest decrease to 46.81% in Qatar. Purslane exhibited activities between 20% and 30% as reported by Sacan and Yanardag (2010) compared with a slight increase of 29.85% indicated by Alam et al. (2014).

These differences in TPC and AC could be the result of several factors. The differences in findings may refer to different periodic and climatic situations, or soil types which impact the nutritious content of various food sources (Ganskopp et al., 2003).

Strengths and limitations of the study

This study highlights novelty and importance by addressing a vital research gap in Qatar, examining the phenolic composition, antioxidant potential, and health benefits of green leafy vegetables. Its local significance aligns with Qatar's developing goal line and possibly

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impacts agricultural practices and nutritional references. The study's inclusive approach includes a varied collection of green leafy vegetables, showcasing methodological consistency in sample extraction and analysis and improving the reliability of the findings. Qualified analysis of total phenolic content (TPC) and antioxidant capacity (AC) values among numerous leafy vegetables generally consumed in Qatar extend the understanding of their health benefit. Despite its strengths, this study had several limitations. Some of the main boundaries of this study include the small sample size, which may influence the statistical power and generalizability of discoveries, the limited diversity of vegetables native to Qatar, constraining insights into phenolic content and antioxidant potential, and the impact of storage on phenolic compounds and antioxidants, which could affect the results over time.

CONCLUSIONS

This study provides valuable data on the phenolic content and antioxidant activity of locally grown green leafy vegetables in Qatar and provides some insight into the potential of these vegetables to positively impact the health and well-being of the population. These findings have implications for dietary recommendations, sustainable agricultural practices, and overall public health in the context of Qatar's dynamic agricultural landscape. As Qatar continues to innovate and diversify its food supply, understanding the nutritional content of locally grown produce is becoming increasingly crucial and serves as a foundational step towards achieving a healthier and more resilient future for the nation. Intensifying further future investigation to embrace a wider phytochemical profile (e.g., flavonoids, carotenoids, vitamin C), varied antioxidant assays (e.g., FRAP, ABTS), and bioavailability tests would expand the understanding of the studied leafy vegetables health benefits. Investigating the effects of environmental influences, and post-harvest dispensation, and relating these greens with interesting species could enhance their use and endorse their implementation. Further, exploring their uses in functional foods, associations with specific health consequences, and consumer attentiveness would improve their value as a maintainable, health-promoting supply in dry regions like Qatar.

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