PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.3153

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RESEARCH ARTICLE

Innovative approach for the assessment of nutritional potential and heavy metal profile in selected wild edible fruits from the major markets of Sargodha division, Pakistan

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OPEN ACCESS

ARTICLE HISTORY

Received: 01 December 2023
Accepted: 04 February 2025

Available online
Version 1.0 : 31 March 2025

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
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CITE THIS ARTICLE

Shah A A, Shah A, Rahim S, Kabir M, Nadeem M, Rios-Escalante P R D . Innovative approach for the assessment of nutritional potential and heavy metal profile in selected wild edible fruits from the major markets of Sargodha division, Pakistan . Plant Science Today (Early Access). https://doi.org/10.14719/pst.3153

Abstract

In the rural areas of Sargodha division, poor and ethnic communities depend on a variety of wild plants for their own consumption and traditional uses. Despite their role in providing variety for family diet, most of wild edible plants are not assessed for their nutritional potential and heavy metal profiling. Hence, the present study was carried out to scrutinize twelve most significant wild edible fruits from the local markets of Sargodha division, Punjab, Pakistan. The species included were *Bauhinia variegata*, *Capparis decidua*, *Citrus limon*, *Cordia dichotoma*, *Ficus palmata*, *Ficus racemosa*, *Mangifera indica*, *Moringa oleifera*, *Morus nigra*, *Phoenix sylvestris*, *Syzygium cumini* and *Ziziphus mauritiana*. The concentrations of seven different heavy metals, viz., Cd, Cu, Fe, Pb, Mn, Ni and Zn in fruits samples were analyzed by using atomic absorption spectrophotometer. Similarly, the nutritional potential of wild fruits through proximate analysis was determined by measuring the contents of moisture (18.4–90.2%), crude protein (0.23–7.79%), crude fat (0.06–4.59%), crude fiber (0.19–33.7%), ash (1.49–9.3%) and nitrogen free extract (47.9–96.7%). Our outcomes uncovered that the metal contents in samples were lower than that detected by different researchers in selected fruits. The layout of total metal contents in fruits was Fe > Zn > Mn > Cu > Ni > Pb > Cd. The study concludes that investigated samples were value added nutraceuticals with no toxicity, so could be utilized as food wealth and traditional remedies in curing malnutrition in the region.

Keywords

malnutrition; nutraceuticals; proximate analysis; remedies; toxicity

Introduction

The term "wild edible plants" (WEPs) refers to plant species that are not cultivated, but exist in natural environment and can be used for food and medication (1). In addition to providing variety for family diet and household herbal preparations, the diversity in wild species also helps to ensure domestic food security (2). In spite of the fact that agricultural crops are the backbone of majority of the societies, the use of WEPs is still a common tradition. Many ethnic communities in emerging nations draw a significant part of their food resources and livelihood from wild plants (3). There is evidence

that more than 300 million people in the modern world rely on forests for all or part of their food and subsistence needs (4). The medicinal uses of WEPs have always been significant in folk traditions throughout the world due to their substantial effects on local communities' health (5). History reveals that humans consume more than 7000 WEPs so far (6), but many of these plant-based food resources and essential medicinal plants still need to be explored.

Pakistan is rich with floral diversity, ethnic origination, varied climatic zones and geographical regions. It also possesses immense diversity of habitats and numerous biodiversity hotspots for wild flora (7). The number of medicinal plants documented in Pakistan is 5700 plant species, with approximately 2000 reported to be actively involved in synthetic drugs (8). Sargodha division is included in Central Punjab, Pakistan with ample plant diversity and local dependency on WEPs for domestic food, medicinal utility and malnutrition (9). Sargodha division was established in 1960 and is comprised of four districts viz., Sargodha, Khushab, Bhakkar and Mianwali extending over an area of 26360 km^2. The biodiversity and landscape of the four districts is quite variable.

The district of Sargodha is primarily characterized by vast cultivated land, interspersed with the gentle slopes of the Kirana hills. In contrast, the landscape of Khushab district features a varied topography, including high mountains, winding valleys and stretches of desert terrain spread across its domain. In addition, the district is home to the globally recognized Salt Range and Soon Valley, both renowned for their abundant biodiversity. District Mianwali is also unique in its landscape comprising of mountains and valleys. Surghar range and Namal valley are located in this district at the border of Khyber Pakhtunkhwa. The fourth district of Sargodha division, Bhakkar, is distinct from the other three with respect to its landscape as well as biodiversity. The mainland of Bhakkar is desert, with the well-known desert, Thal, located in this district. The greater part of the population of Sargodha region dwells in rural areas and confront numerous difficulties. For example, urbanization, overpopulation, limited opportunities for livelihood, food scarcity and unaffordable rise in the prices of food items and synthetic drugs are some of the hardships faced by the population of Sargodha division (10). Farming is the main occupation in the territory. However, less attention is paid by the government for poor rustics and farmers in context of food and healthcare facilities. Along these lines, they still rely upon WEPs to combat malnutrition, challenging health problems and income insecurity. The fruits from majority of WEPs are consumed raw, some are sold at festivals or in rural markets and very few are pickled or otherwise preserved for use during dry seasons (9). However, in the current context, this tradition is rapidly waning as a result of continued developmental projects, flow of migrants from rustic to metropolitan zones, declining natural resources, changing ecological conditions, habitat loss and deforestation. The loss of indigenous knowledge in an area is parallel to the loss of local biodiversity (11). So, it is a prime need to analyze data about popular uses of WEPs of Sargodha division and aim at providing relevant information. This information could be beneficial to develop innovative means of nutraceuticals for local communities and rescue the knowledge from disappearing.

The heavy metal contamination in soil and their accumulation in plants are mainly caused by polluted water used for irrigation, industrial emissions, pesticides and fertilizers (12). However, there is evidence indicating that soil derived from mineral rocks naturally harbors significant levels of major minerals such as calcium (Ca), magnesium (Mg) and potassium (K), along with trace elements like iron (Fe), copper (Cu) and zinc (Zn) (13). The efficiency of WEPs for medicinal worth depends on concentration of trace metals (14). Trace minerals play bioactive role in treating various ailments. However, their concentrations above certain limits cause toxic effects (15). Micronutrients, such as cobalt (Co), Cu, Fe and Zn, are essential for human health when present at appropriate levels. However, when these metals exceed safe limits, they are classified as heavy metals. Heavy metals are a group of metallic elements that have high atomic weight and density. They include metals such as lead (Pb), mercury (Hg), cadmium (Cd) and arsenic (As), among others. These metals are often toxic to living organisms, including humans, even at relatively low concentrations (16). Heavy metal toxicity in humans can result in serious health issues such as neurological disorders, renal damage and reproductive problems. Screening plants for heavy metals is essential to prevent contaminated food from entering the food chain, safeguard human health and maintain environmental integrity. It also helps ensure compliance with regulatory standards and preserve crop quality for sustainable agriculture.

Assessment of heavy metal content and nutritional composition of WEPs is very scanty in our country (10). There is not a single study on the nutritional potential and heavy metal profiling of wild edible fruits commonly sold in markets of Sargodha division. Therefore, the present study was conducted to evaluate nutritional significance and toxic effects of wild edible fruits from the territory. Such kinds of studies are highly advocated for any dietary intake (17). In summary, addressing the lack of analysis in these areas is essential for safeguarding public health, promoting food security and ensuring sustainable utilization of natural resources (9).

Materials and Methods

Ethno-geography of the study area

Sargodha division, comprising of district Sargodha, Khushab, Mianwali and Bhakkar (Fig. 1), not only contains beautiful agricultural fields but also mountainous and desert areas. The only desert (Thal) is found in district Khushab and Bhakkar (9). Indus, Chenab and Jhelum, being the major rivers of the country stream through the area. The highest temperatures are recorded in June (up to 50°C) with temperature fall in January (up to 0°C) (9). In some areas of the region, such as Sakesar (Soon Valley, Khushab),

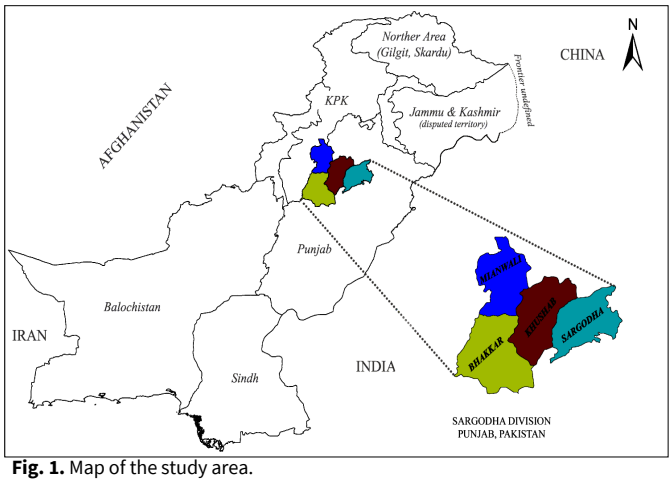

Fig. 1. Map of the study area.

winter temperatures can drop below zero degrees Celsius with occasional snowfall (18). Being the capital of the territory, Sargodha receives annual rainfall about 21.87 mm. Topographically, this area of the Punjab is in the middle of the province and is home to many different ethnic and racial tribes. A high proportion of the locals live as rustics or ranchers. But many of them work as part-time shepherds. The indigenous people in Sargodha and Khushab districts speak Punjabi while in Mianwali and Bhakkar they speak Saraiki dialect. The majority of the population in the area is directly or indirectly involved in farming, which is the primary source of income in the area. In Pakistan, about 80% human population lives in rural vicinities where WEPs are easily accessible (19). Some considerable numbers of inhabitants in the territory get their earnings from wild edible fruits and medicinal plants. Depending on perishability of ripe fruits, different stockpiling and grasping techniques are followed in the local markets after the harvesting of wild natural products from plants.

Ethno-medicinal documentation

Ancient villages in the division Sargodha were focused as the sites for field data on ethnomedicinal applications of WEPs. The major fieldwork activities included sample collection, data documentation and photography of plant specimens during January 2021 to March 2022. Information was gathered from local inhabitants including traditional healers (Hakeems), herbalists (Saniasies), rustics, fruit vendors and housewives by implementing previous techniques for gathering ethno-botanical data (20). During the study, 72 key informants, aged from 25 to 80 years, were selected randomly, of which 55 were males and 17 females. The comprehensive demographic information of the participants is compiled in Table 1.

The field survey was conducted through village walks, one-on-one interviews, semi-structured interviews (40 interviews in total) and focus group discussion (21). The questionnaire was designed to record ethnomedicinal recipes, local name, part(s) used, modes of usage and applications (22). The social bio-data on age, gender, experience and educational background was also documented (Table 1). Uncultivated lands, rural and urban markets of ancient towns of the region, particularly Bhera, Jhawrian, Miani, Dharema, Jandanwala, Mankera, Waan Bhachran, Kamar Mashani, Katha Saghral and Sakaesar, were visited for data and sample collection. The investigated fruit species were identified by comparing with the "Flora of Pakistan" (23). The list of plants was finalized after verification from "The Plant List" (http://www.theplantlist.org) for the botanical nomenclature of species. The voucher specimens were deposited in the herbarium of University of Sargodha (SARGU) for future reference.

Table 1. Demographic data of informants participated in study

Variables	Categories	No. of persons	Percentage
Informant section	Traditional healers (Hakeems)	14	19
	Herbalists (Saniasies)	7	10
	Indigenous People (rustics)	15	21
	House wives	12	17
	Fruit venders	24	33
Gender	Male	55	76
	Female	17	24
Age group	25–40	15	21
	41–70	43	60
	More than 70 years	14	19
Education level	Illiterate	18	25
	Five years of education	29	40
	Six to ten years of education	18	25
	Above ten years of education	7	10
Experience of traditional health practitioners (hakeems/saniasies)	5 years	6	29
	5–10 years	5	24
	10–20 years	7	33
	More than 20 years	3	14

The relative frequency of citation (RFC) and frequency of citation (FC)

To analyze documented data, various quantitative indices including the frequency of citation and relative frequency of citation were tabulated for each species. The FC is the proportion of respondents who mentioned the use of a particular plant species. RFC was calculated by using the following formula (24):

$$RFC = FC / N \quad \text{.....(Eqn. 1)}$$

Where the total number of study participants is N. The RFC value varies from "0", when no one mentions a plant useful, to "1", when every study informant referred to the plant as useful (10, 24).

Sample collection

The raw fruits were gathered from rural and urban markets of Sargodha and preserved in the laboratory of the Institute of Food Science and Nutrition (IFSN), University of Sargodha to analyze proximate parameters and heavy metal contents. A small quantity of each fruit sample as well as vegetative specimen was dried and retained in the University herbarium (SARGU), for the purpose of fact-finding in future.

Digestion of fruit samples

Fruit samples were subjected to wet digestion method. For this, 1 g dried sample was taken in a flask, separate for each sample and 4 mL of hydrogen peroxide (H_2O_2) and 2 mL of sulfuric acid (H_2SO_4) were added to it. The digestion was carried out by placing samples in digestion chamber for 30 min at suitable temperature. After the completion of the digestion procedure, 2 mL of H_2O_2 were added in every flask and entire samples were reheated to make them colourless. Further the digested samples were filtered and the volume of all samples was increased to 50 mL, which were finally stockpiled in plastic containers until analysis (25).

Experimental procedure for heavy metals determination

The concentration of copper, iron, manganese, nickel cadmium, zinc and lead in the samples was measured by utilizing atomic absorption spectrophotometer (25, 26).

Proximate analysis

The evaluation of proximate parameters is a vital strategy to check nutritive worth of a plant sample (27). These analysis were successfully completed in IFSN, University of Sargodha as per standard laboratory procedures (28). All proximate values were calculated in percentage of dry matter.

Moisture content determination

The procedure began by weighing the fresh sample. Subsequently, the weighed sample was placed in an oven set at a temperature of 105°C, until a constant weight was achieved (9). Then moisture content in percentage was calculated by the following formula (28):

$$\text{Moisture (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad \text{.....(Eqn. 2)}$$

Where, W_1 = Initial weight of sample and W_2 = Weight of dried sample

Crude protein determination

For crude protein determination, Micro Kjeldahl apparatus was used to estimate nitrogen value in the sample. Initially, the sample was subjected to digestion procedure to breakdown organic material and release nitrogen in the form of ammonium ions (NH_4^+) (25). Subsequently, the mixture was titrated to separate the content of nitrogen and then protein content was obtained by conversion of nitrogen percentage to protein using the formula (28):

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times \text{conversion factor (6.25)} \quad \text{.....(Eqn. 3)}$$

Crude fat determination

Soxhlet apparatus was used to determine crude fat in samples. First of all, a weighed quantity of fruit sample was taken in Soxhlet thimble and placed in Soxhlet apparatus. Then petroleum ether was poured into Soxhlet flask which was heated to vaporize the solvent. The vaporized solvent was percolated through the sample, extracting the fat. The extracted fat was dried in oven until constant weight was achieved. Then it was weighed and calculated by the following formula (28):

$$\text{Crude Fat (\%)} = \frac{\text{Weight of fat extracted}}{\text{Weight of sample}} \times 100 \quad \text{.....(Eqn. 4)}$$

Crude fiber determination

In the process of crude fiber determination, 2 g powder sample was subjected to digestion procedure to separate the insoluble residue (28). The residue was washed with distilled water until the washings were neutral and then dried in an oven to obtain a constant weight. The crude fiber content was calculated by using following formula (28):

$$\text{Crude Fiber (\%)} = \frac{Ws - Wr}{Ws} \times 100 \quad \text{.....(Eqn. 5)}$$

Where, Ws = Initial weight of sample and Wr = Weight of residue

Ash content determination

The content of ash in fruit samples was determined solely to estimate inorganic matter in fruit samples. In the ash content determination procedure, fruit sample was taken in a dry crucible, which was then kept in muffle furnace above 500°C for 6 h. The sample was incinerated for complete combustion. The crucible was then cooled and ash content was determined by using the following formula (9):

$$\text{Ash Content (\%)} = \frac{\text{Weight of ash residue after incineration}}{\text{Weight of sample}} \times 100 \quad \text{.....(Eqn. 6)}$$

Nitrogen free extract (NFE) determination

After obtaining the values of ash, crude fat, crude fiber and crude protein through their specific determination procedure, NFE was determined by using following formula (9):

NFE = 100 - % (ash + crude fat + crude fiber + crude protein)

.....(Eqn. 7)

Statistical analysis

The data were analyzed statistically by using the ANOVA and software Minitab 16. Differences in means were calculated by LSD test.

Results and Discussion

According to demographic information, the group of people who were interviewed consisted of 76% males and 24% females in the local community of division Sargodha. Of these, 19% were Hakeems, 10% Saniasies, 21% rustics, 17% housewives and 33% fruit vendors. As indicated by age differentiation, 21% were between 25 and 40 years old, 60% between 41 and 70 years and 19% showed above 70 years of age (Table 1). The popularity of wild fruits in the region was mainly due to their exceptionally good taste and affordable price than other fruits (29). There was no tenable data concerning the yield and trade of fruits and other organic products from the wild in the area. The factual movement of food items from harvest to the consumer or commercial center was actually not as simple as delineated. Perishability of ripe fruits remains a significant factor influencing their storage or preservation for commercial supply and hence, different stockpiling and grasping techniques were followed in region after the harvesting of wild natural products from plants. It was observed that the post-harvest loss of different kinds of fruits varied on the basis of perishability, handling procedures, nature of source plant and ecological factors. Therefore, the most transient fruits (in ripe form) were unable to reach marketplace while the others were easily transported from remote areas to the rural and urban markets. Similarly, vacillation in the cost of the fruits was quite rampant and the gatherers had no authority over it as they lacked knowledge about the non-damaging strategies and activities for worth addition with the market acting as an obstruction in dealing with the conditions. The sale prices of marketable wild fruits are represented in the Table 2.

Traditional phytotherapy is an aptitude practiced by proficient traditional healers whose experience-based knowledge is appreciated by everybody. They are famous for their traditional cures to treat ailments at local level (30). The written record of useful medicinal plants has revolutionized the introduction of modern drugs (31). Till date, this field occupies much interest in poor countries as most of their population resides in remote areas (32). Sargodha division is the land with fertile agricultural plains, WEPs and medicinal flora. Ajnala village in district Sargodha, Jandanwala in district Bhakkar and Soon Valley in district Khushab are fertile for wild plant diversity. Similarly, a few zones in Mianwali district, such as Kundal and Makarwal, are well inhabited by plant biodiversity (13). Our survey confirmed that the traditional use of herbal preparations is decreasing day by day due to the lack of belief of the new generation, which considers it as a matter of superstition. Our findings align closely with those reported in previous studies (33).

According to our ethno-botanical survey, all the investigated fruits were found safe from any toxic effect (Supplementary Table 1). The wild plants with medicinal significance provide cheap and harmless drugs of natural origin and pose no risks to users. The participants in our study pointed out a lot of ailments including stomach disorders, chest complaints, constipation, cardiovascular disorders, skin diseases, diabetes, obesity, fever, sexual weakness, dehydration, body weakness, asthma, blood and bone problems, inflammation, intestinal worms, jaundice, mouth gums, piles, rheumatism, insect sting and others which were handled through various home-grown prescriptions (Supplementary Table 1) and affirmed by an earlier study (33). After comparison with ethno-botanical record, it became evident that the uses of medicinal plants

Table 2. Sale price range of selected wild fruits

S. No..	Name of fruit species	Local name	Price range (*Rs/Kg)	Average
1	*Bauhinia variegata*	Kachnar	400 – 550	475
2	*Capparis decidua*	Dela	300 – 500	400
3	*Citrus limon*	Nimbu	400 – 450	425
4	*Cordia dichotoma*	Lasura	350 – 450	400
5	*Ficus palmata*	Injeer	300 – 530	415
6	*Ficus racemosa*	Gular	350 – 460	405
7	*Mangifera indica*	Amb	150 – 200	175
8	*Moringa oleifera*	Sohanjna	250 – 330	290
9	*Morus nigra*	Shahtoot	250 – 400	325
10	*Phoenix sylvestris*	Doka	380 – 500	440
11	*Syzygium cumini*	Jaman	120 – 200	160
12	*Ziziphus mauritiana*	Ber	150 – 250	200

*RS= Pakistani rupees.

in current study were mostly same as reported in other parts of the world, particularly, the uses of *M. nigra* and *Z. mauritiana* were found similar to those of other research groups (33–38). Fruits of *F. palmata* were noted laxative and used to treat ulcer, bronchitis, eczema, constipation and sexual weaknesses. Moreover, fruits of the plant were found effective to improve eye vision and even as laxative (33, 39). The fruits of *P. sylvestris*, in raw form, were utilized to cure body weakness and bone problems, but few researchers pointed out its use to treat constipation, abdominal pain and vomiting (33, 40). In the matter of mode of application of traditional herbal preparations, 86% were applied internally and 14% externally (Fig. 2).

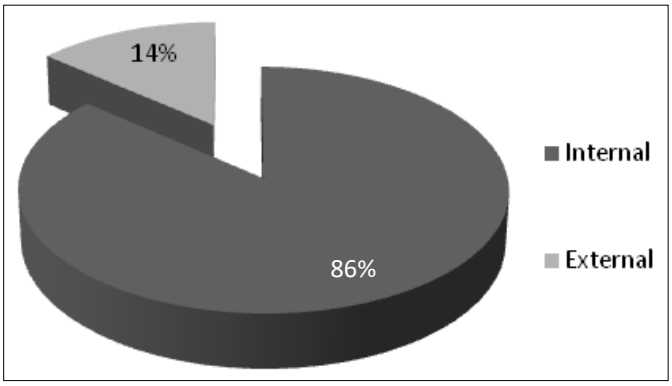

Fig. 2. Mode of application of folk recipes.

The information on WEPs was analyzed quantitatively for FC and RFC values. The RFC for *C. limon* is the highest (0.972) followed by *S. cumini* (0.958), *P. sylvestris* (0.944), *M. oleifera* (0.903) and *C. dichotoma* (0.847) and the least value of RFC was observed for *F. racemosa* (0.264) and *F. palmata* (0.542) (Fig. 3). The WEPs with higher RFC value indicate that these medicinal plant species are easily accessible to the general public and vigorously consumed to overcome a lot of complications all through the area. These findings are strongly confirmed by earlier studies (33, 38). A few species of WEPs were very quick in treating the diseases and were found profoundly used by the occupants of the Sargodha division. In case of WEPs on the basis of FC and RFC, important uses of *C. limon* are indiges-

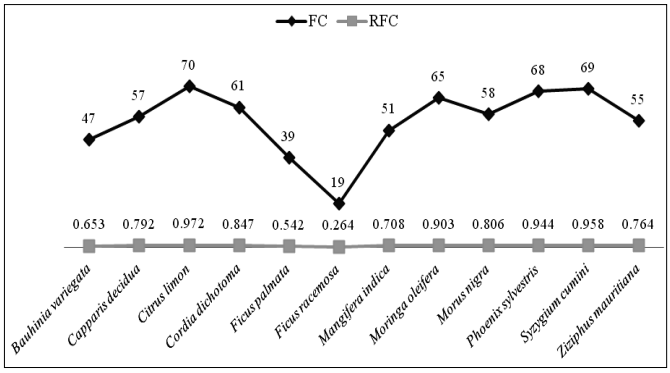

Fig. 3. Measurement of quantitative indices.

tion, high cholesterol, hypertension, stomach ache and skin diseases, *P. sylvestris* is used for body weakness, bones problem, sexual weakness and fatigue, *M. oleifera* as liver tonic and for blood diseases, diabetes, inflammation, constipation, ulcer, diabetes, body weakness and stomach complaints, *S. cumini* for cooling, astringent, anti-diabetic, vomiting, dyspepsia, leucorrhea, fever, dysentry and coughs, *M. nigra* for relief of tonsils, liver disorders, sore throat, thirst, purgative, astringent and anthelmintic, *Z. mauritiana* as pectoral, blood purifier, digestive, astringent, pectoral, to cure chest complaints, gonorrhea, skin infection, rheumatism, indigestion, fever and menstrual problems, *C. decidua* for cardiac disorders, biliousness, pyorrhea, sacroiliac pain, remittent fevers, boils, swellings and gingivitis, *F. palmata* for constipation, nutritive, sexual weaknesses, laxative, ulcer, bronchitis, eczema, stings, insect bite, pimples and prickles, *M. indica* as diaphoretic, astringent, laxative, tonic and to alleviate cough, body weakness and stomach ache, *B. variegata* as astringent, cough and chest complaints, haemorrhoids, blood purification and indigestion, *C. dichotoma* for Sexual weakness, dehydration and constipation and *F. racemosa* for the treatment of cough, sexual weakness, leucorrhea and glucose in urine (Supplementary Table 1).

Table 3 lists the amount of specific heavy metals (mg/kg) present in the fruits of WEPs. Our findings clearly show that the fruit samples had higher concentrations of Fe, Mn and Zn (Fig. 4). The highest Fe content was

Table 3. The content of heavy metals (mg/kg) in the fruit samples

Sample	Parameters (mean ± SD)						
	Fe	Cu	Mn	Cd	Ni	Zn	Pb
Bauhinia variegata	0.212± 0.2	0.04± 1.05	1.10± 0.25	BDL	0.009± 0.01	3.72± 0.1	0.03± 0.01
Capparis decidua	3.57±0.02	0.052± 0.8	0.09± 0.01	BDL	0.04± 1.01	0.32± 0.25	BDL
Citrus limon	0.57± 0.01	BDL	0.94± 0.45	0.002± 0.2	BDL	4.17± 2.15	0.05± 0. 5
Cordia dichotoma	0.021± 0.1	0.06± 0.07	0.05± 0.2	BDL	0.005± 0.01	0.05± 0.1	0.08± 2.15
Ficus palmata	12.7± 2.15	BDL	0.97± 0.15	BDL	0.010± 2.15	3.93± 0.25	0.022± 0.1
Ficus racemosa	7.14±0.02	0.31± 0.05	1.39± 0.22	BDL	0.02± 0.05	0.09± 0.1	BDL
Mangifera indica	5.43± 0.01	BDL	0.78± 3.1	0.003± 0.1	BDL	1.03± 1.05	BDL
Moringa oleifera	27.1 ± 0.1	1.017±0.02	1.43±1.05	BDL	0.003± 2.03	1.07±0.373	0.10±2.23
Morus nigra	14.32± 3.1	0.35± 2.15	1.88± 0.25	BDL	BDL	5.48±0.02	BDL
Phoenix sylvestris	21. 3± 0.5	1.01± 0.8	1.69± 0.5	BDL	0.031± 0.02	2.27± 3.1	BDL
Syzygium cumini	6.32± 0.9	0.46± 0.05	1.13± 0.65	0.001± 0.3	BDL	1.12± 0.05	BDL
Ziziphus mauritiana	4.52± 3.1	0.39± 0.01	1.41± 0.15	0.005± 0.6	0.03± 1.01	3.01± 1.05	0.001± 0.2

BDL= below detection level, SD= standard deviation.

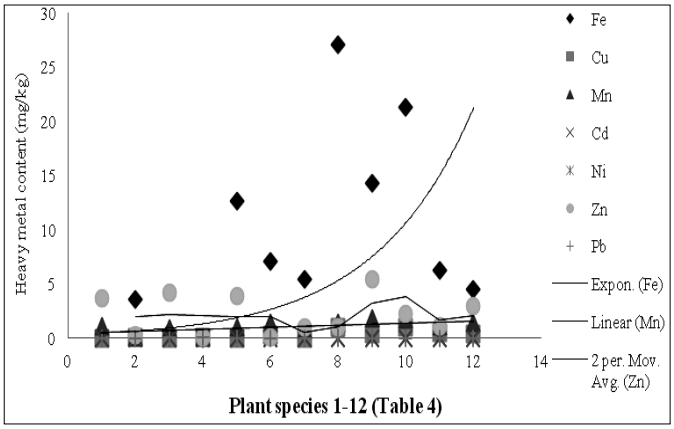

Fig. 4. Heavy metal contents in fruits of WEPs.

observed in *M. oleifera* (27.1±0.1 mg/kg) followed by *P. sylvestris* (21.3±0.5 mg/kg), *M. nigra* (14.32±3.1 mg/kg) and *F. palmata* (12.7± 2.15 mg/kg). This plant's exceptionally high Fe content demonstrated the uptake and enrichment of the metal, which might be employed as a food supplement to treat rural poor people's iron deficiency. As a micronutrient, average daily intake of Fe, however, was found to be within the World Health Organization (WHO) maximum tolerable daily intake limits of 56 mg/day (41, 42). Zinc, considered vital for immunomodulatory functions in humans, was another metal found in higher concentration (43, 44). Its content in the current study ranged from 0.05±0.1 mg/kg in *C. dichotoma* to 5.48±0.02 mg/kg in *M. nigra*. Previous study detected Zn concentration in the same range (3.61 mg/kg) in *Z. mauritiana* (44). However, the overall Zn concentration in this study was lower than that found in other plants (44). The current study's Zn concentration was also lower than the daily intake limits of 21 mg/day of Zn (42). Similarly, the measured level of Mn was higher than all the other metals detected in present study (Table 3), but lower than that reported by earlier study (44). Its content varied from 0.05± 0.2 mg/kg in *C. dichotoma* to 1.88±0.25 mg/kg in *M. nigra*. The permissible limit of Mn in plants defined by Food and Agriculture Organization of United Nation (FAO)/WHO is 2 mg/kg (44). Thus, the data from the current study shows that the Mn concentration in the edible parts of all the WEPs investigated was lower than the proposed limit for toxicity. Other metals were in minute quantity and even below detection level (BDL) in some plants (Table 3). The Pb content in investigated fruit samples was ranging between 0.001±0.2 mg/kg in *Z. mauritiana* and 0.10±2.23 mg/kg in *M. oleifera*. These values are much lower than maximum permissible weekly intake limits of 1.750 mg/week or daily intake limits of 0.25 mg/day set by WHO (44). Six fruit samples showed BDL Pb concentration. However, detectable Pb content in some fruits may be due to anthropogenic activities in urban markets (45). Copper is also a significant heavy metal causing toxicity when its concentration exceeds above certain level. But Cu content determined in present research (0.04±1.05 to 1.017±0.02 mg/kg) is below maximum daily intake limit of 35 mg/day set by WHO (42, 44). Cadmium was the metal which showed BDL content in maximum samples and ranged from 0.001±0.3 to 0.005±0.6 mg/kg. All the investigated fruit samples showed less accumulation of Cd than its daily intake limits of 70 mg/day (42, 44). However, detectable concentration of Cd in the fruit samples of *C. limon*, *M. indica*, *S. cumini* and *Z. mauritiana* may be due to anthropogenic activities (45, 46). The nickel content determined in present research work was ranged from 0.003±2.03 to 0.04±1.01 mg/kg (Table 3). Four plants showed content in BDL but the detectable amounts of Ni in other samples may be due to urban contamination and other anthropogenic reasons.

The proximate values of the studied fruits of WEPs are presented in Table 4. Overall results from our study showed that the moisture contents varied between 18.4±2.3 and 90.2±0.12%, crude protein contents ranged from 0.23±1.02 to 7.79±2.01%, crude fat between 0.06±1.02 and 4.59±0.3%, crude fiber from 0.19±0.55 to 33.7±0.6%, ash from 1.49±0.01 to 9.3±0.14% and NFE varied between 47.9±0.5 and 96.7±0.15%.

The moisture values in our study are highly confirmed by the previous reports on the wild edible fruits indicating the moisture content varied between 9.360

Table 4. Proximate composition (%) of selected wild edible fruits

Fruit species	Parameters (mean ± SD)					
	Moisture	Crude protein	Crude fat	Crude fiber	Ash	NFE
Bauhinia variegata	54.2±0.79	3.45±1.01	0.16±0.01	3.22±0.85	4.91±2.05	65.2±1.46
Capparis decidua	53.1±0.86	1.59±0.5	1.69±0.03	5.32±0.01	2.17±0.01	72.0±0.02
Citrus limon	90.2±0.12	0.61±0.21	0.06±1.02	0.19±0.55	4.49±1.02	47.9±0.5
Cordia dichotoma	71.1±0.86	2.72±0.01	0.53±0.01	0.91±0.01	1.49±0.01	88.0±0.02
Ficus palmata	27.6±1.11	1.74±0.01	3.8±1.02	7.19±0.79	5.49±1.02	86.4±1.33
Ficus racemosa	75.1±3.12	0.92±0.11	4.59±0.3	33.7±0.6	7.2±0. 5	55.5±1.4
Mangifera indica	78.3±0.15	0.23±1.02	0.43±0.01	2.91±0.08	2.64±0.39	61.8±0.31
Moringa oleifera	18.4±2.3	7.79±2.01	2.73±1.03	11.1±0.90	4.38±0.91	52.0±0.2
Morus nigra	80.1±0.22	0.77±0.17	0.63±0.11	6.31±0.8	9.3±0.14	91.3±2.21
Phoenix sylvestris	62.3±0.55	0.81±0.01	0.12±0.03	2.19±0.18	5.45±0.05	96.5±3.5
Syzygium cumini	72.5±0.56	1.53±0.33	1.87±0.01	1.65±0.07	2.35±0.09	96.7±0.15
Ziziphus mauritiana	66.4±1.6	0.84±0.51	0.17±0.2	0.88±0.09	1.60±0.10	94.8±3.44

SD= standard deviation.

(*Olea ferruginea*) to 84.053% (*Azadirachta indica*) (9). The results are also comparable with other previous study (47). Slight variations in our study may be due to the fact that moisture content is largely dependent on harvest time of the species and environmental factors like humidity and temperature. More than 70% moisture contents shown by the fruits of *C. limon*, *M. nigra*, *M. indica*, *F. racemosa*, *S. cumini* and *C. dichotoma* indicated their significance as an alternate source of water. The moisture content determined in our study holds significant implications for the shelf life of the fruits. Higher moisture levels, as found in species such as *C. limon* (90.2%), *M. nigra* (80.1%) and *M. indica* (78.3%), may contribute to their reduced shelf life due to elevated susceptibility to microbial infection and enzymatic degradation. Contrarily, species with lower moisture content, like *M. oleifera* (18.4%), *F. palmata* (27.6%) and *C. decidua* (53.1%), may possess enhanced shelf life by minimizing conditions favorable to spoilage. Understanding this variation in moisture values is essential for determining optimal storage conditions or preservation for wild edible fruits.

The maximum crude protein was found in *M. oleifera* (7.79±2.01%) and minimum in *M. indica* (0.23±1.02%). This protein content was little higher than that obtained in previous study in WEPs (9). However, our results were on the same line as reported by other similar study (48). Good protein content in *M. oleifera* (7.79±2.01%), *B. variegata* (3.45±1.01%) and *C. dichotoma* (2.72±0.01%) indicated that these plant species could be adopted as a cheap source of protein for rustic poor individuals. The range of crude fat contents in current study (0.06±1.02 to 4.59±0.3%) was strongly supported by earlier studies (9, 47). Its maximum contents were obtained from *F. racemosa* (4.59±0.3%) and minimum from *C. limon* (0.06±1.02%). Overall, fat contents were less than 5% in all the studied fruits, which indicated their efficacy as nutraceuticals for obese individuals. Our study results indicated maximum fiber content in *F. racemosa* (33.7±0.6%) followed by *M. oleifera* (11.1±0.90%) and *F. palmata* (7.19±0.79%), while minimum in *C. limon* (0.19±0.55%). This range of fiber contents in WEPs is verified by the outcomes of previous research studies (9, 49). Actually, the crude fibers represent indigestible part of human nutrition and are ultimately beneficial for treatment of constipation and carbohydrate deficiency. So, the fruits of plants such as *F. racemosa*, *M. oleifera* and *F. palmata* could be utilized as a source of dietary fibers. Ash values in samples are actually the level of major and trace minerals and other inorganic compounds (50). *M. nigra* had highest ash content (9.3±0.14%) followed by *F. racemosa* (7.2±0. 5%), *F. palmata* (5.49±1.02%) and *P. sylvestris* (5.45±0.05%). Overall range of ash contents (1.49±0.01 to 9.3±0.14%) in the present study is validated by previous research (9). The research groupworked on *C. decidua* in different areas of Punjab and determined its ash content ranging equal to 1%, which strengthen our outcomes (9). NFE content in average indicated that all the studied fruits from WEPs were significant source of digestible carbohydrates. The maximum value of NFE contents was shown by *S. cumini* (96.7±0.15%) while minimum by *C. limon* (47.9±0.5%). These results are supported by previous study (9). It is worth mentioning that the investigated fruit samples were highly enriched with carbohydrates, making them a significant source of energy for consumers. A good quantity of carbohydrates in fruits also indicates their sweetness.

Conclusion

The current research study is the first of its kind in the Sargodha Division, assessing the heavy metals and nutritional potential of wild edible fruits for nutrition in indigenous communities. It is evident from the results that these plant species are treasures of important nutraceuticals for local community. In addition to this, these are alternate source of earnings for farmers and ranchers with great deal of market potential. Quantitative estimations of FC (19–70) and RFC (0.264–0.972) revealed that home grown plant-based preparation is still a noteworthy tradition practiced by indigenous communities. Overall, the scientific proofs of our study validated that these wild edibles contained substantial amount of nutrients and were safe from heavy metal toxicity. They were enriched with moisture, carbohydrates, minerals, dietary fibers, iron, zinc and manganese. This appraisal demonstrates an effective and long-lasting summary that can facilitate the safeguarding of knowledge about the use of WEPs in the territory, trying to reassure future generations' interest in traditional healing practices. Although studies on nutritional status of wild medicinal plants in Pakistan are gaining much needed importance, there is still a need for active exploration of data on nutritional components of unexplored species together with increased endeavors for the sustainable use of these wild sources of nutrition. The potential species need to be conserved in their natural habitats before it becomes too late. Moreover, domestication of these species is strongly recommended to improve the economic condition of the local people.

Acknowledgements

This scholarly article is the part of PhD research appraisal of Asif Abbas Shah. The authors gratefully acknowledge the practical and technical support from Department of Botany, University of Sargodha, Sargodha, Pakistan. The authors are also indebted to the racial tribes, indigenous communities and fruit merchants for their active participation and assistance. The authors also extend their appreciation to IFSN and SARGU, University of Sargodha, Sargodha, Pakistan for providing the necessary resources and facilities to complete this study.

Authors' contributions

AAS conducted research design studies and drafted the manuscript. AS supervised the entire research work. SR performed the statistical analysis. MK critically reviewed the manuscript. MN cross checked citations and PR provided financial support for this manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

Supplementary data

Supplementary Table 1. Ethnobotanical information on wild edible plants of the study area

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