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Iron Content of Major Cereal Grains Grown in Sindh, Pakistan: A Nutritional Baseline for Addressing Iron Deficiency Anemia in a High-Burden Province

Zahid H Shar[1], Noor Rahman[2], Jatesh Kumar[1], Muhammad Arsalan Mahmood[3], Abdul Razaq[4]

[1]Dr M.A Kazi Institute of Chemistry, University of Sindh, Jamshoro, Sindh, Pakistan.
[2]Lab Technologist, KMU IPDM Peshawar, KP, Pakistan.
[3]Department of Food Science and Technology, School of Food and Agricultural Sciences, University of Management and Technology, Lahore, Punjab, Pakistan.
[4]School of Chemistry, University of the Punjab, Lahore, Punjab, Pakistan.

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Correspondence to: Zahid H Shar, Dr M.A Kazi institute of chemistry University of Sindh Jamshoro, Sindh Pakistan
Email: zahidshar_2009@yahoo.com

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ABSTRACT

Iron content in cereal grains may be best way to overcome iron deficiency anemia (IDA). In this regard Iron content in six different cereal grains grown in Sindh were determined by using spectrophotometric method. One hundred 180 samples collected from eight districts representing Sindh's key agro-ecological zones. The iron content in Peral millet was found to be highest 42.18 ± 4.67 mg/kg followed by barley (38.56 ± 5.12 mg/kg), sorghum (36.91 ± 4.89 mg/kg), wheat (34.82 ± 4.23 mg/kg), maize (22.37 ± 3.45 mg/kg). The lowest iron content was found in rice 12.45 ± 2.87 mg/kg. Comparatively higher content of Iron was found in samples collected from Upper Sindh ($p < 0.001$). This survey provides a baseline information to guide food fortification, dietary diversification, and biofortification strategies to combat IDA in Sindh, Pakistan.

1. INTRODUCTION

Iron deficiency anemia (IDA) is the most common nutritional disorder which affects 1.4 billion people worldwide with higher number from low to middle income countries in south Asia and sub-Saharan Africa (Organization, 2008). The most severe public health emergency in the country was reported in a survey conducted by the national nutrition and found fifty four percent children and forty four percent women suffered from IDA (NNS, 2018). Sindh is the second most populous province of Pakistan and relatively larger number cases reported from here, which needs proper attention and dietary substitutions. Therefore, understanding the iron content of various cereal grains is essential for selecting the most suitable cereal grains (Akhtar et al., 2013).

Inadequate dietary iron intake due to high phytate content in cereal-based diets and recurring reproductive cycles in women are some of the multifactorial causes of iron deficiency in Sindh (Bhutta et al., 2013). The majority of households in Sindh consume 65–80% of their daily calories from cereal grains, especially rice and wheat (FAO, 2022). Cereals offer significant amounts of macronutrients, but their contribution to dietary iron is still debatable because they include phytic acid and other anti-nutritional elements that chelate iron and decrease its absorption in the digestive system (Bosscher, 2001).

Sindh accounts for over twenty five percent of Pakistan's wheat production, making it one of the top ten countries in the world. In addition to wheat, the province grows a variety of other cereal crops such as rice, barley, jowar (sorghum), bajra (pearl millet) and maize (PBS, 2024). Even though these cereals are essential to the local diet, but there is a lack of information in the literature about the iron content in these cereal crops cultivated in Sindh (Naveed et al., 2020). Millets and coarse grains are the main food supply are for marginalized agricultural populations in the province's dry and semi-arid districts, have received little attention (Kapoor et al., 2024).

Therefore, the current study was undertaken to fill this important knowledge gap by performing a thorough district-representative evaluation of the iron content of six major cereal grains grown in the province of Sindh and to establish a nutritional baseline that can inform evidence-based interventions for reducing iron deficiency anemia in this high-burden province.

2. MATERIALS And METHODS

2.1 Chemicals and Reagents

Chemical and reagents used in this study were of analytical grade. Nitric acid, perchloric acid, ferric chloride, hydrogen peroxide was purchased from the sigma. Ferric chloride was used to prepare Standard iron solution (1000 mg/L Fe). Deionized water used throughout the process. A UV-Visible double-beam spectrophotometer (Shimadzu UV-1900, Japan) equipped with quartz cuvettes were used for iron content determination.

2.2 Sample Collection and Preparation

One hundred eighty grain samples were collected from eight districts of Sindh. Samples were collected on the basis of difference in agro zone as shown in Table 1. One kg of each cereal grain was procured from local grain markets, flour mills, and farm-level sources to ensure representative sample. Thirty individual samples (3–4 samples per district) were collected and pooled by cereal species from each district to create composite samples for analysis. All cereal grains samples were cleaned manually to remove dust, stones, husks, and other foreign materials and washed. The dried grains were ground in a stainless-steel mill to pass through a 0.5 mm sieve. Iron was determined after wet digestion as described by (Qureshi et al., 2002). Five grams of floor Sample was digested with sulfuric acid, perchloric acid and nitric acid in ratio (1:2:3). Iron was determined in Fe^{3+} state; by reacting with thiocyanate to form a reddish-brown complex in the presence of the hydrogen peroxide and its absorbance was measured at wavelength 480 nm. A stock solution of 1000mg/L was prepared from ferric chloride from which individual working standard of 5, 10, 15, 20, and 25 mg/L were prepared.

2.3 Statistical Analysis

SPSS software was used for statistical analysis. For every cereal grain, descriptive statistic was computed. The iron content of the six cereal varieties was compared using one-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) post-hoc test. To evaluate the connections between iron concentration and Agro-ecological factors, Pearson's correlation coefficient was calculated. For every test, a p-value of less than 0.05 was deemed statistically significant.

Table 1

Details of cereal grain samples collected from Sindh province for iron analysis.

Cereal Grain	Scientific Name	Samples (n)	Collection Districts
Wheat	*Triticum aestivum*	30	All 8 districts
Rice	*Oryza sativa*	30	Karachi, Hyderabad, Larkana, Dadu, Badin
Barley	*Hordeum vulgare*	30	Khairpur, Sukkur, Larkana, Dadu
Bajra	*Pennisetum glaucum*	30	Nawabshah, Mirpurkhas, Dadu, Khairpur
Maize	*Zea mays*	30	Karachi, Hyderabad, Nawabshah, Dadu
Jowar	*Sorghum bicolor*	30	Khairpur, Dadu, Nawabshah, Sukkur

3. Results and Discussion

The iron content in different types of cereal grains varied significantly and are presented in Table 2. Bajra had shown the highest mean iron concentration 42.18 ± 4.67 mg/kg, followed by barley 38.56 ± 5.12 mg/kg and jowar 36.91 ± 4.89 mg/kg. The most popular cereal in Sindh, wheat, had an iron content of 34.82 ± 4.23 mg/kg. The province's second most significant cereal, rice, had the lowest iron concentration of 12.45 ± 2.87 mg/kg, while maize had a moderate iron content of 22.37 ± 3.45 mg/kg.

The difference in iron concentration in cereal grains was found to be statistically significant by one-way ANOVA ($F (5, 174) = 128.6$, $p < 0.001$). The pairwise differences were further defined by Tukey's HSD post-hoc test, which revealed that rice had a substantially lower iron content than all other grains ($p < 0.01$) and bajra had a significantly greater iron content than all other cereals ($p < 0.01$). Both barley and jowar had significantly greater iron contents than wheat ($p < 0.05$), but there was no discernible difference between them ($p = 0.347$).

The study's findings indicate that the iron content in cereal grains from Sindh follows this descending order: bajra, followed by barley, jowar, wheat, maize, and rice. The universal awareness that small millets and sorghum are often better providers of dietary iron than ordinary wheat and rice is in line with this ranking, which has been supported by multiple research studies conducted in South Asia and sub-Saharan Africa (Hemalatha et al., 2007; Vasan et al., 2014).

Table 2

Iron content (mg/kg dry weight) of six cereal grains from Sindh, Pakistan.

Cereal Grain	n	Mean ± SD (mg/kg)	Range (mg/kg)
Bajra (Pearl Millet)	30	42.18 ± 4.67	33.5 – 51.2
Barley	30	38.56 ± 5.12	28.4 – 48.7
Jowar (Sorghum)	30	36.91 ± 4.89	27.8 – 47.3
Wheat	30	34.82 ± 4.23	25.6 – 44.8
Maize	30	22.37 ± 3.45	16.2 – 29.8
Rice	30	12.45 ± 2.87	7.3 – 18.9

Earlier reports from Pakistan found a comparable concentration of iron in wheat and found values of iron in the range of 30.5 to 38.2 mg/kg (Abbas & Ahmad, 2018; Ikhtiar & Alam, 2007; Rahim et al., 2022). Similarly, (Aslam[1] et al., 2025) documented iron content of 35.1 ± 4.0 mg/kg in wheat samples from different ecological zones of Pakistan. The iron values observed for wheat are broadly consistent with those reported by (Qureshi et al., 2002) found values of 36.0–49.1 mg/Kg in Pakistani wheat varieties. Similarly, rice iron content in the present study aligns with findings of (Anjum et al., 2007), who reported a range of 5.9–39.8 mg/Kg, and with (Zubair et al., 2012), who found 10.8–15.2 mg/kg for Pakistani rice. The comparatively low iron concentration in rice is well-established in the literature and is primarily attributed to the removal of iron-rich bran layers during polishing and milling (Gibson et al., 2010). For barley, the values obtained in this study are consistent with those of (Kanwal et al., 2023) found 24.1–98.7 mg/Kg, and (Khalil et al., 2025), who recorded 78.1 ± 0.05 mg/Kg.

Present study findings support previously published data and reinforce the nutritional superiority of coarse grains, particularly bajra and jowar, as dietary sources of iron in cereal-consuming populations of Sindh. Significant regional variations in iron content were found in the district-level investigation, which can be explained by the intricate interactions between soil properties, irrigation techniques, and post-harvest treatment. In comparison to samples from lower Sindh and coastal areas, samples from upper Sindh districts which include Khairpur and Larkana consistently displayed increased iron concentration across a variety of cereal varieties. This pattern is in line with the known soil chemistry of Sindh, where iron-rich sediments from upstream catchments resulting in higher concentrations of bioavailable iron (WAPDA, 2022)

3.1 Public Health Implications

The results of this study carry higher public health relevance, where iron deficiency anemia is most important nutritional burden, particularly among children and women. The marked variation in iron content across the six cereal grains analyzed provides evidence to support a strategic shift in dietary patterns. Promoting the consumption of bajra, jowar, and barley through culturally acceptable food preparations such as bajra roti, jowar porridge, and barley-supplemented foods offers a practical and cost-effective intervention. Furthermore, incorporating these cereals into school feeding programs could improve iron intake level for children

Given that rice is the most consumed cereal in lower Sindh, A targeted fortification through coating, dusting, or extrusion techniques could be implemented here as done in different countries (Hackl, 2017). Furthermore, the district-level iron variability identified in this study can guide geographically focused biofortification programs. Collaboration with PARC and Sindh Wheat Research Institutes to develop iron-rich cultivars suited to calcareous soils, alongside agronomic biofortification using Fe-EDDHA and Fe-DTPA chelates, represents a sustainable and long-term strategy (Buturi et al., 2023; Jahan & Tar'an, 2023). These evidence-based interventions underscore the translational value of iron profiling studies in shaping nutrition-sensitive agricultural and public health policy.

4. CONCLUSION

This study presents the first province-wide assessment of iron content in six major cereal grains cultivated in Sindh, Pakistan, utilizing the spectrophotometric method. Results demonstrated that bajra (pearl millet) exhibited the highest iron concentration (42.18 ± 4.67 mg/kg), followed by barley, jowar, wheat, maize, and rice (12.45 ± 2.87 mg/kg), with statistically significant differences observed among cereal types ($p < 0.001$). Based on these findings, the study suggests dietary diversification based on iron content and making iron fortification through different techniques could be viable way to eliminate the iron deficiency. These findings provide a critical evidence-based information on iron content to guide targeted interventions against iron deficiency anemia in Sindh.

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