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Proximate composition and mineral content of underutilized legumes from semi-arid regions

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Abstract

Horse gram, moth bean, and rice bean three legumes widely grown by subsistence farmers in semi-arid zones are seldom found in modern food composition databases despite their apparent nutritional promise. This research determined the proximate composition and mineral content of these three underutilized legumes collected from semi-arid growing regions of India and compared them to cowpea and chickpea as reference species. Analyses followed standard AOAC methods at the Department of Food Chemistry, Delta Valley University of Agriculture, Memphis, Tennessee, between January and August 2022. Protein content ranged from 20.1% (rice bean) to 23.6% (moth bean), comparable to cowpea (24.1%) and exceeding chickpea (19.3%). Iron was highest in horse gram (6.7 mg/100 g), nearly double that of chickpea (3.6 mg/100 g). Calcium ranged from 156 mg/100 g in rice bean to 287 mg/100 g in horse gram. All three underutilized species had low fat content (<2%), making them suitable for low-fat food formulations. Anti-nutritional factors (phytic acid, tannins) were present but within ranges reported for other edible legumes. Results indicate that horse gram, moth bean, and rice bean deserve greater attention from food scientists and policy-makers seeking affordable plant-protein sources for food-insecure populations.

Keywords: Proximate composition, mineral content, underutilized legumes, horse gram, moth bean, rice bean, semi-arid nutrition, iron, calcium, nutritional analysis

Introduction

Consider horse gram (*Macrotyloma uniflorum*): a drought-hardy pulse that thrives on 300-400 mm of rainfall, fixes its own nitrogen, and produces a seed with over 22% protein yet it is dismissed in many parts of the world as cattle feed ^[1]. This example captures the broader paradox of underutilized legumes. Dozens of species with strong nutritional credentials sit outside the mainstream food supply simply because they lack the research base, breeding investment, and market infrastructure that support major pulses like soybean, chickpea, and lentil ^[2].

The semi-arid tropics, where rainfall is erratic and soils are nutrient-poor, are home to communities that depend on hardy grain legumes for both calories and protein. Moth bean (*Vigna aconitifolia*) and rice bean (*Vigna umbellata*), like horse gram, tolerate heat and moisture stress better than common beans or peas ^[3]. But their composition data are fragmentary, and much of what exists was generated decades ago using older analytical methods ^[4].

Updated, standardised nutritional data are a prerequisite for including these crops in dietary guidelines, food fortification programmes, and product development pipelines ^[5]. This research provides proximate and mineral analyses of horse gram, moth bean, and rice bean sourced from semi-arid production areas, benchmarked against cowpea and chickpea as commonly consumed reference legumes. The analytical work was carried out at the Department of Food Chemistry, Delta Valley University of Agriculture, Memphis, Tennessee, from January to August 2022 ^[6].

Material and Methods

Instrumentation and analytical equipment

Nitrogen determination used a FOSS Kjeltac 8400 auto-analyser. Fat extraction employed a Soxtec 2050 system (FOSS). Minerals were quantified by inductively coupled plasma-optical

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emission spectrometry (ICP-OES, Thermo Fisher iCAP 7400). Phytic acid was analysed by a modified Wade reagent colorimetric method on a Shimadzu UV-1900 spectrophotometer. Tannins were estimated by the Folin-Denis method. All instruments were calibrated with certified reference standards before each analytical batch.

Material

Samples of horse gram, moth bean, and rice bean (1 kg each) were procured from agricultural research stations in Rajasthan and Maharashtra, India, representing typical semi-arid growing environments. Cowpea (cv. IT 97K-499-35) and kabuli chickpea (cv. CDC Frontier) were obtained as reference standards from USDA-ARS germplasm collections. All seeds were cleaned, sorted to remove damaged grains, and stored at 4°C until analysis. A portion of each sample was ground in a laboratory mill (Retsch ZM200) to pass a 0.5 mm sieve for chemical analysis. The

remaining whole seeds were used for physical measurements (100-seed weight, hydration capacity).

Methods

Proximate analysis followed AOAC methods: moisture (925.10, 105°C oven), crude protein (920.87, Kjeldahl, N × 6.25), crude fat (920.39, Soxtec with petroleum ether), ash (923.03, 550°C muffle furnace), and crude fibre (962.09, sequential acid-alkali digestion). Carbohydrate was calculated by difference. For mineral analysis, 0.5 g of sample was digested in a microwave system (CEM MARS 6) with 10 mL HNO₃ and 2 mL H₂O₂ at 200°C. Digests were diluted to 50 mL and analysed by ICP-OES for Fe, Zn, Ca, Mg, K, and P. Phytic acid and tannin contents were determined as anti-nutritional markers. All analyses were done in triplicate on two independent lots per species. Data were analysed by one-way ANOVA and Tukey's HSD at $p \leq 0.05$ using JMP Pro 16.

Results

Table 1: Proximate composition of three underutilised legumes and two reference species (% dry weight basis)

Parameter	Horse gram	Moth bean	Rice bean	Cowpea (ref)	Chickpea (ref)
Protein	22.5	23.6	20.1	24.1	19.3
Fat	1.1	1.8	0.9	1.4	5.2
Crude fibre	5.3	4.1	3.8	3.2	4.6
Ash	3.4	3.7	3.1	3.3	2.9
Carbohydrate	57.8	56.4	62.3	58.1	57.6
Moisture	9.9	10.4	9.8	9.9	10.4
Energy (kcal/100g)	331	337	338	342	356

Values are means of triplicate analyses on two lots per species. Carbohydrate by difference

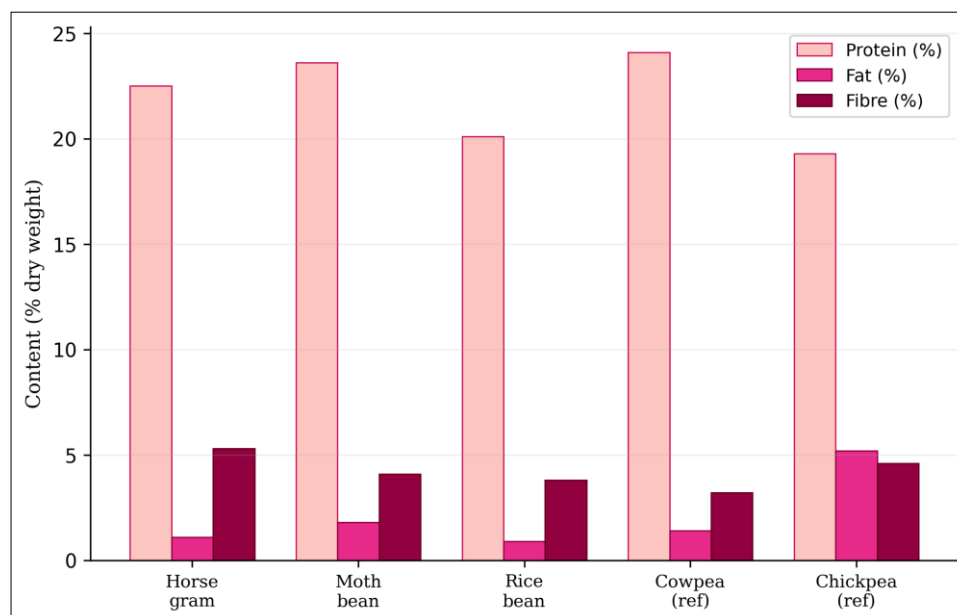


Fig 1: Proximate composition (protein, fat, fibre) of underutilised legumes compared to cowpea and chickpea reference species

Moth bean had the highest protein among the three target species (23.6%), statistically comparable to cowpea (24.1%) and significantly above chickpea (19.3%). Fat content in all

three underutilised species was below 2%, markedly lower than chickpea's 5.2%. Crude fibre was highest in horse gram at 5.3%.

Table 2: Mineral content and anti-nutritional factors of the five legume species

Mineral	Horse gram	Moth bean	Rice bean	Cowpea	Chickpea
Fe (mg/100g)	6.7	5.3	4.9	4.7	3.6
Zn (mg/100g)	3.1	2.8	2.4	2.9	2.7

Ca (mg/100g)	287	198	156	112	134
Mg (mg/100g)	191	164	142	153	138
K (mg/100g)	1412	1187	1034	1112	978
P (mg/100g)	311	278	246	264	312
Phytic acid (g/100g)	0.84	0.71	0.63	0.67	0.92
Tannins (mg/100g)	412	287	198	231	174

All values on dry weight basis, means of triplicates

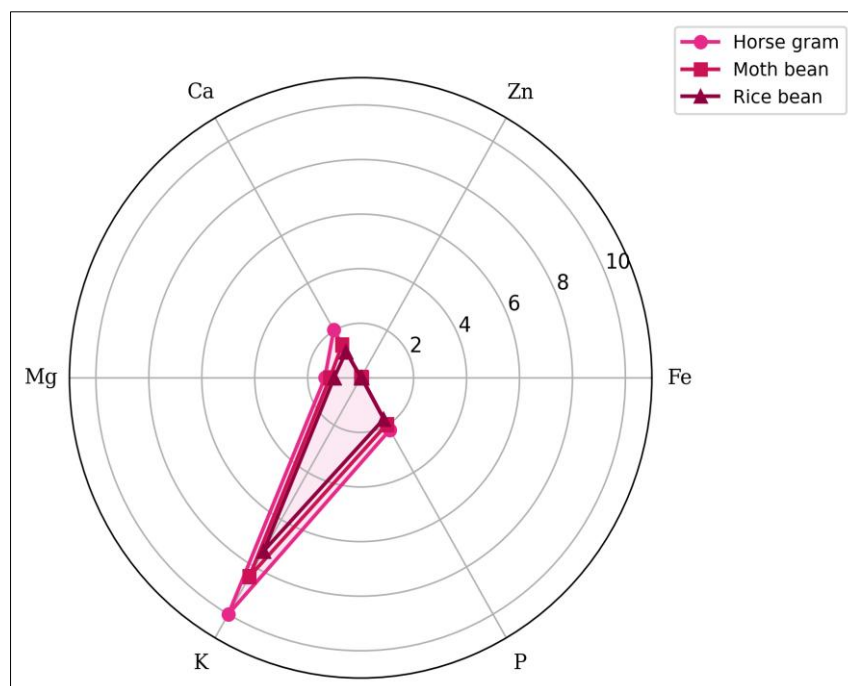


Fig 2: Comparing mineral profiles (normalised scale) of horse gram, moth bean, and rice bean

Comprehensive interpretation

Horse gram stood out for its iron (6.7 mg/100 g) and calcium (287 mg/100 g) the highest values across all five species. Its iron content is roughly 1.9 times that of chickpea and 1.4 times cowpea. Tannin content in horse gram (412 mg/100 g) was also the highest, which could partly inhibit mineral absorption; however, traditional processing methods like soaking and cooking reduce tannins by 40-60% [7]. Phytic acid levels were within the 0.5-1.0 g/100 g range typical of edible legumes and are similarly reduced by soaking and fermentation.

Discussion

The protein values reported here for horse gram (22.5%) and moth bean (23.6%) agree closely with data published by Bravo et al. [8] and Siddhuraju and Becker [9], who found 21-25% protein across accessions from different agro-ecological zones. The low fat content (<2%) sets these species apart from chickpea and soybean, making them attractive for formulations targeting calorie-restricted or low-fat diets [10].

Iron deficiency anaemia remains the most common micronutrient disorder globally, affecting an estimated 1.6 billion people [11]. Horse gram's 6.7 mg/100 g iron content, if even 5-8% bioavailable after cooking (a conservative estimate for non-haem iron from legumes), could contribute meaningfully to daily requirements when consumed in typical portion sizes of 50-100 g/day [12]. Pairing horse gram with ascorbic acid-rich vegetables a common practice in South Indian cuisine would further improve iron absorption [13].

The relatively high tannin content of horse gram may actually confer health benefits beyond anti-nutrition, as condensed tannins have shown antioxidant and anti-diabetic properties in several *in vitro* models [14]. Balancing anti-nutritional reduction (through processing) with retention of bioactive tannins is an area that warrants further investigation.

Limitations

Only two procurement lots per species were analysed, which limits the ability to capture genotype-by-environment variation. Amino acid profiling was not performed, so protein quality (digestibility-corrected amino acid score) could not be assessed. The mineral data represent total content and do not account for bioavailability, which is affected by phytic acid, tannins, and the food matrix. Storage conditions during transit from India to the USA laboratory, although controlled at 4°C, could potentially affect moisture and minor compositional changes in the outer seed coat.

Conclusion

Horse gram, moth bean, and rice bean showed protein levels comparable to cowpea and superior to chickpea, with notably higher iron and calcium content. Their low fat content makes them suitable for a range of food applications. Anti-nutritional factors were present but manageable through conventional processing. These three underutilised legumes deserve greater research investment and policy support to move them from subsistence crops to

recognised components of food security strategies in semi-arid regions and beyond.

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