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Nutritional assessment and anti-diabetic potential of indigenous bitter gourd varieties

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Abstract
Type 2 diabetes affects over 77 million adults in India, and dietary management through functional foods is gaining traction as a first-line preventive measure. Bitter gourd (*Momordica charantia* L.) has long been used in traditional medicine for blood sugar regulation, but comparative data on the nutritional and anti-diabetic properties of Indian indigenous varieties are sparse. This research evaluated six indigenous bitter gourd varieties collected from Gujarat and Rajasthan for proximate composition, mineral and vitamin content, charantin concentration, and *in vitro* anti-diabetic activity through α-amylase and α-glucosidase inhibition assays. MC-84 showed the highest charantin content (3.24 mg/g dry weight) and strongest α-glucosidase inhibition (IC_{50} = 38.7 µg/mL), followed by Arka Harit. Protein content ranged from 1.67 to 2.43 g/100g fresh weight. A strong positive correlation (r = 0.91) was found between charantin content and α-glucosidase inhibition. MC-84 and Arka Harit are recommended as superior varieties for functional food development targeting diabetic management.

Keywords: Nutritional assessment, anti-diabetic activity, bitter gourd, *Momordica charantia*, charantin, α-glucosidase inhibition, indigenous varieties, functional food, medicinal vegetables, bioactive compounds

Introduction
India faces a diabetes epidemic of staggering proportions: the International Diabetes Federation estimates that 77.2 million Indian adults live with type 2 diabetes, a figure projected to exceed 134 million by 2045 [1]. Pharmacological interventions, while effective, carry side effects and compliance challenges that have renewed interest in dietary approaches to glycaemic control [2]. Bitter gourd stands out among candidate functional vegetables because its hypoglycaemic properties are supported by both centuries of traditional use and a growing body of clinical evidence [3].

The anti-diabetic activity of bitter gourd is attributed mainly to charantin, a steroidal saponin that stimulates insulin secretion and improves peripheral glucose uptake, and to polypeptide-p, an insulin-like compound [4]. Vicine, momordicin, and other alkaloids contribute additional bioactivity through α-amylase and α-glucosidase inhibition, which slows carbohydrate digestion and blunts postprandial glucose spikes [5]. However, these bioactive concentrations vary widely among genotypes, and most published data come from East Asian or African cultivars rather than Indian landraces [6].

Gujarat and Rajasthan harbour considerable bitter gourd diversity in both cultivated varieties and semi-wild forms maintained by tribal farming communities [7]. Screening this germplasm for nutritional quality and anti-diabetic potential could identify superior varieties for breeding programmes and functional food product development. This research characterised six indigenous varieties for proximate composition, mineral and vitamin profiles, charantin content, and *in vitro* enzyme inhibition activity [8].

Extraction protocol
Freeze-dried bitter gourd fruit powder (10 g) was extracted with 80% methanol (100 mL) by maceration at room temperature for 48 h with intermittent shaking. The extract was filtered through Whatman No. 1 paper and concentrated under reduced pressure at 40°C using a rotary evaporator. The crude methanolic extract was stored at -20°C until analysis. For charantin estimation, a separate portion was extracted with chloroform-methanol (2:1, v/v)

followed by silica gel column chromatography as described by Pitipanapong *et al*. [9]. Extract yield ranged from 11.3 to 14.8 g/100g dry weight across varieties.

Phytochemical screening

Qualitative screening of methanolic extracts confirmed the presence of saponins (frothing test), alkaloids (Dragendorff's reagent), flavonoids (shinoda test), tannins ($FeCl_3$ test), and glycosides (Keller-Killiani test) in all six varieties. Terpenoids were detected by the Salkowski test. MC-84 and Arka Harit showed the most intense positive reactions for saponins and alkaloids, consistent with their higher charantin values [10].

Material and Methods

Material

Six indigenous bitter gourd varieties Priya, Arka Harit, Pusa Do Mausami, MC-84, Konkan Tara, and Phule Green Gold were collected from the germplasm repository at Anand Agricultural University, Gujarat, and farmer fields in Ajmer district, Rajasthan, during Kharif 2023. Fruits were harvested at the green mature stage (18-20 days post-anthesis), washed, deseeded, sliced, and freeze-dried at -80°C for 48 h. All chemicals were of analytical grade from Merck and HiMedia [11].

Methods

Proximate analysis (moisture, ash, crude protein, fat, fibre, carbohydrate) followed AOAC methods. Minerals (Fe, Zn, Ca, Mg) were determined by atomic absorption spectrophotometry after wet digestion. Vitamin C was estimated by the 2,6-dichlorophenol indophenol method. Total phenolics were measured using the Folin-Ciocalteu reagent with gallic acid equivalents. Charantin was quantified by HPLC (C18 column, UV detection at 204 nm). Anti-diabetic potential was assessed through α-amylase (dinitrosalicylic acid method) and α-glucosidase (p-nitrophenyl glucopyranoside method) inhibition assays with acarbose as positive control. IC_{50} values were calculated by non-linear regression. All analyses were done in triplicate and data subjected to ANOVA with DMRT at P=0.05 [12].

Results

Table 1: Proximate composition and bioactive content of six indigenous bitter gourd varieties

Variety	Protein (g/100g)	Fibre (g/100g)	Vit. C (mg/100g)	Fe (mg/100g)	Total Phenolics (mg GAE)	Charantin (mg/g DW)	α-Glucosidase IC_{50} (µg/mL)
Priya	1.82	1.43	84.3	1.87	312.4	2.41	57.3
Arka Harit	2.18	1.67	91.7	2.14	347.8	2.87	43.8
Pusa Do Mausami	1.67	1.31	78.6	1.63	289.1	2.13	64.1
MC-84	2.43	1.89	96.4	2.38	381.6	3.24	38.7
Konkan Tara	1.94	1.52	87.1	1.94	328.3	2.64	51.2
Phule Green Gold	1.78	1.38	82.9	1.76	301.7	2.31	59.6
CD (P=0.05)	0.21	0.14	6.38	0.19	24.7	0.28	5.84

MC-84 recorded the highest protein (2.43 g/100g), vitamin C (96.4 mg/100g), iron (2.38 mg/100g), total phenolics (381.6 mg GAE), and charantin (3.24 mg/g DW) among all varieties (Table 1). The strongest α-glucosidase inhibition was also in MC-84 (IC_{50} = 38.7 µg/mL), compared with acarbose positive control (IC_{50} = 31.2 µg/mL). Arka Harit ranked second across most parameters. Pusa Do Mausami consistently showed the lowest bioactive concentrations.

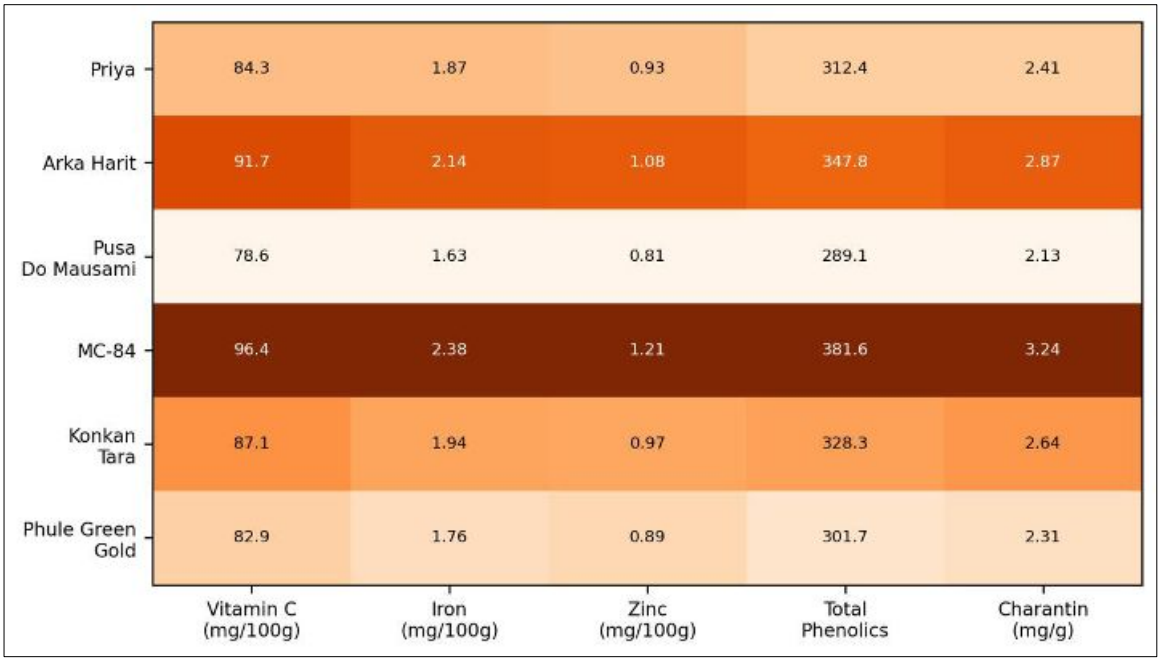

Fig 1: Heatmap of normalised nutrient and bioactive content across six indigenous bitter gourd varieties

The heatmap visually confirms MC-84's dominance across all measured parameters. Arka Harit consistently occupied the second tier, while Pusa Do Mausami and Phule Green Gold clustered at the lower end.

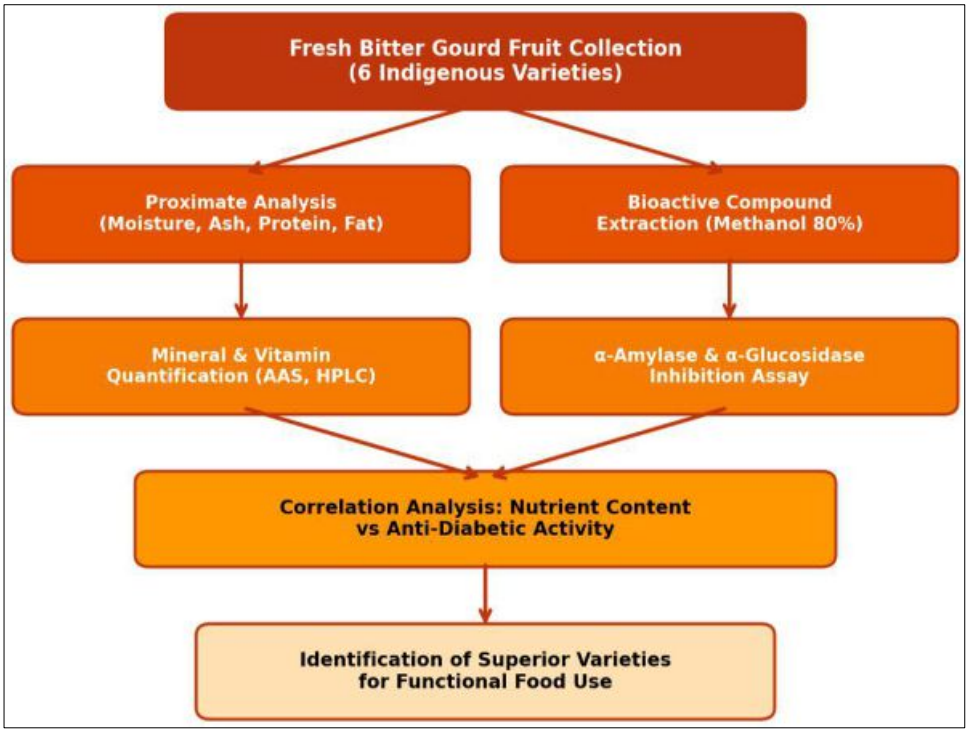

Fig 2: Process diagram of the analytical workflow from fruit collection through anti-diabetic activity assessment

Comprehensive interpretation

The strong correlation between charantin content and enzyme inhibition activity (r = 0.91 for α-glucosidase) suggests that charantin-rich varieties like MC-84 and Arka Harit offer the most promise for functional food applications targeting glycaemic control.

Discussion

The charantin range of 2.13-3.24 mg/g dry weight across our six varieties falls within values reported for East Asian cultivars (1.8-4.1 mg/g) but sits at the higher end of the Indian germplasm spectrum, suggesting that western Indian landraces harbour considerable bioactive diversity [6, 13]. MC-84's α-glucosidase IC_{50} of 38.7 µg/mL approaches the potency of acarbose (31.2 µg/mL), a commercially prescribed α-glucosidase inhibitor, which is remarkable for a crude methanolic extract rather than a purified compound [5].

The strong charantin–enzyme inhibition correlation (r = 0.91) aligns with the mechanistic understanding that charantin enhances cellular glucose uptake through GLUT4 translocation and simultaneously suppresses carbohydrate-digesting enzymes at the intestinal brush border [4, 14]. However, α-amylase inhibition showed a weaker correlation (r = 0.73), implying that non-charantin compounds such as vicine and momordicin contribute more to amylase suppression [15]. Nutritionally, MC-84's high protein and iron content make it doubly attractive for populations where micronutrient deficiency and diabetes co-exist, a common scenario in rural Gujarat and Rajasthan [16].

A limitation of this research is its reliance on *in vitro* assays; *in vivo* validation using animal models or human feeding trials is needed before clinical recommendations can be made [17].

Conclusion

MC-84 emerged as the most nutritionally dense and bioactive variety among the six indigenous bitter gourd genotypes tested, with the highest charantin (3.24 mg/g), strongest α-glucosidase inhibition (IC_{50} = 38.7 µg/mL), and superior protein and mineral content. Arka Harit was a close second. These two varieties are recommended for inclusion in functional food development programmes and breeding efforts aimed at enhancing the anti-diabetic value of bitter gourd. *In vivo* confirmation of their glycaemic effects should be a priority for follow-up work.

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