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Horse Gram (*Macrotyloma uniflorum*), an Underutilised Pulse with Therapeutic Potential in Urolithiasis and Metabolic Disorders

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Abstract

Non-communicable diseases such as urolithiasis, obesity, and type 2 diabetes are rising exponentially amidst food blandness and ultra-processed food dependency, necessitating low-budget, food-based interventions. The current review justifies renewed attention towards horse gram (*Macrotyloma uniflorum*), a forgotten, climate-resilient pulse eminently mentioned in *Ayurveda* for litholytic and metabolic activity. We see glaring gaps: fragmented pharmacology in isolated models, unsatisfactory standardisation of extracts, scarce comparative metabolomics, and a virtual absence of well-constructed human trials. Our innovation unifies agronomy, ethnomedicine, nutrition, phytochemistry, and pharmacology into one history for urolithiasis and metabolic diseases. We synthesise evidence on primary and secondary metabolites, screen *in vitro* crystallisation and enzyme inhibition, evaluate *in vivo* nephrolithiasis and metabolic models, and monitor how processing, such as soaking, germination, fermentation, and extrusion influence antinutrients and bioavailability. Findings identify several activities: inhibiting calcium oxalate nucleation and aggregation, enhancing diuretic action through citrate and magnesium, modulating carbohydrate enzymes, and exhibiting antioxidant, anti-inflammatory, and AMPK-associated antiadipogenic activities. This research places horse gram in the food that helps people stay healthy. It not only satisfies the protein requirement but also reduces the risk to metabolism and the kidneys. It also indicates cheap methods of processing the grain that increase its potency without becoming harmful. The findings link old concepts to scientific concepts, providing a model that can be applied in public health nutrition. For India, particularly Uttarakhand and other arid zones, the relevance is to integrate a drought-resistant crop with preventive medicine, crop diversity, and

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health-promoting food use. Lastly, we recommend further research on standardised extracts, dosage, and clinical trials to help farmers, policymakers, and physicians transform *Kulthi* from a forgotten legume to a health food.

Major Findings: Horse gram shows potential as a functional food with antiurolithiatic and metabolic benefits. Its bioactive compounds help prevent calcium oxalate crystallisation and improve glucose and lipid metabolism, while soaking, germination, and fermentation can further enhance its efficacy.

Keywords: Agronomy, Functional Food, Healthcare, Metabolic Disorders, Nutrition, Phytochemistry

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1. Introduction

Pulses are at the hub of world food and nutrition security, offering inexpensive sources of proteins, dietary fibres, minerals, and phytochemicals crucial to human health. Among these, underutilised and neglected legumes are progressively being identified as climate-resilient crops with significant potential in nutrition and functional foods. Horse gram (*Macrotyloma uniflorum*), grown in dryland soils of South Asia and Africa, is one such underexploited pulse with agronomic tolerance coupled with high medicinal potential[1]. *Ayurveda* and other traditional medicine systems address horse gram as *Kulthi* and suggest its application in urinary calculi (*mutrakrichha*), obesity, arthritis, and metabolic disorders[2]. Worldwide, non-communicable diseases like obesity, diabetes, and urolithiasis are increasing at epidemic levels. Altered lifestyles, low dietary variety, and dependency on packaged foods are among the most prominent causes[3]. In such a scenario, less-utilised legumes like horse gram have attracted increased attention due to their bioactive components with antioxidant, anti-inflammatory, enzyme inhibition, and diuretic potential[4]. These characteristics justify *Ayurvedic* assertions and show the potential for preventive and therapeutic uses[5].

Nutritionally, horse gram contains a high amount of proteins, calcium, iron, dietary fibre, phenolic acids, and flavonoids, making it appropriate to treat protein-energy malnutrition and micronutrient deficiencies[6]. Pharmacologically, seed and seed coat extracts exhibit antiurolithiatic activity by blocking the crystallisation and aggregation of calcium oxalate *in vitro* and *in vivo*[7]. Recent crystallisation assays further establish its function in inhibiting calcium oxalate crystal growth[8]. Anti-obesity and antidiabetic effects have also been observed in animal and *in vitro* studies, including α-amylase and α-glucosidase inhibition, lipid regulation, and postprandial glycaemic regulation[9]. However, there is a lack of comprehensive research on horse gram despite these observations. Pharmacological studies are mostly done on isolated models, and agricultural and nutritional literature underestimates its medicinal potential[10]. Metabolomics profiling reveals its promising potential as a nutraceutical, but clinical trials have not been performed yet[11]. Improvement of germplasm also reveals genetic diversity in nutritional traits that can be tapped for functional food production[12].

The versatility of horse gram is further established by processing and food technology studies. The nutraceutical properties of horse gram are enhanced by germination, fermentation, and heat processing, which enhance the bioavailability of phenolics and decrease antinutritional components[13]. Functional foods fortified with horse gram flour have shown enhanced antioxidant activity, better mineral bioavailability, and higher acceptability. These results further strengthen the use of horse gram as a healthy food and medicinal herb in modern times[14]. However, there is still a gap in the literature. Although *Ayurvedic* and folk medicine highly recommend *Kulthi* for the treatment of kidney stones and metabolic disorders, there is a lack of empirical research. *In silico* studies of horse gram phytoconstituents show interaction with enzymes responsible for oxalate synthesis, thus providing mechanistic support for its preventive role in urolithiasis[4]. Comparative studies with other medicinal herbs further confirm its antioxidant and antiurolithiatic activity. This paper proposes to compile the existing literature on horse gram, focusing on its therapeutic value in urolithiasis and metabolic disorders[5]. The review combines *Ayurvedic* literature, nutritional and phytochemical composition, and pharmacological studies, explaining mechanisms of

action and research gaps. A unique aspect of this review is its interdisciplinary nature, combining traditional knowledge with modern data to revive interest in horse gram as a functional food and a medicinal plant for addressing global health issues[15].

2. Materials and Methods

2.1 Literature Search

A systematic review of literature was conducted from March to August 2025 to find meaningful studies on *Macrotyloma uniflorum* (horse gram) and its medicinal application in urolithiasis, metabolic disorders, and related diseases. Leading electronic databases such as PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar were used. Keywords and Boolean operators used were: "*Macrotyloma uniflorum*" OR "horse gram" OR "*Kulthi*" AND (urolithiasis OR kidney stones OR nephrolithiasis OR diabetes OR obesity OR metabolic disorders OR phytochemicals OR functional food). *Ayurvedic* and ethnobotanical literature were searched using AYUSH portals, Google Books, and classical texts. The inclusion items were original research papers, reviews, ethnopharmacological reviews, and clinical/preclinical trials in English from 2000 to 2025. Non-full-text articles, those without primary data, and those not on therapeutic aspects were excluded. Reference lists of the searched papers were manually searched to identify other studies. The methodology as a whole covered extensively agronomic, nutritional, pharmacological, and ethnomedicinal evidence for horse gram's therapeutic potential.

3. Botanical Characteristics and Taxonomy

The botanical classification of horse gram is shown in Table 1.

3.1 Morphology

The plant is an annual, twining or trailing herb, adapted to dryland ecosystems as shown in Figure 1.

Table 1. Taxonomic classification of Horse gram

Rank	Classification
Kingdom	Plantae
Sub-kingdom	Tracheobionta (Vascular plants)
Superdivision	Spermatophyta (Seed plants)
Division	Magnoliophyta (Angiosperms)
Class	Magnoliopsida (Dicotyledons)
Subclass	Rosidae
Order	Fabales
Family	Fabaceae (Leguminosae)
Subfamily	Papilionoideae
Genus	*Macrotyloma*
Species	*Macrotyloma uniflorum* (Lam.) Verdc.



Figure 1. Plant of Horse gram.

- Plant: Grows as a slender, branched climber or trailing herb up to 60–90 cm in height. Stems are green, angular, and often hairy.
- Leaves: Trifoliate with ovate to lanceolate leaflets, 2–7 cm long, slightly hairy on both surfaces.
- Flowers: Small, pale yellow to light green, typically borne singly or in small racemes; corolla is papilionaceous, as characteristic of legumes.
- Pod: Linear, slightly curved, 4–7 cm long, containing 5–7 seeds. Pods turn brown at maturity.
- Seed: Small, flattened, kidney-shaped; seed coat varies in colour from brown, reddish-brown, black to mottled patterns depending on the variety.

4. Ecotypes and Variability Across Regions

Horse gram shows wide variability in seed size, shape, and colour, reflecting its adaptation to diverse agro-climatic zones. Also, horse gram is known by different name in all over India, as shown in Table 2.

- In South India, small-seeded brown and black ecotypes are common, often used for medicinal decoctions.
- In the Himalayan foothills and North India, relatively larger-seeded ecotypes are cultivated, valued both as food and fodder.
- In Africa, landraces exhibit variability in drought tolerance, flowering time, and growth habit.
- Germplasm evaluations reveal significant diversity for traits such as seed protein content, phenolic compounds, and days to maturity, providing opportunities for breeding nutritionally superior and stress-resilient varieties.

5. Chemical Constituents

5.1 Primary Metabolites and Nutritional Matrix

Horse gram (*Macrotyloma uniflorum*) is also a nutrient-rich legume, which is mainly eaten in dryland areas. Seeds have 22–28% protein with high concentrations of albumins and globulins, 55–60% carbohydrate, and 1–3% fat, constituting a balanced food for protein–energy nutrition[16]. The dietary fibre level is fairly high (10–12%), with the potential to aid satiety, glycaemic control, and better gut health. Micronutrient content reveals legume to be a rich source of iron (7–9 mg/100 g), calcium (250–300 mg/100 g), molybdenum, phosphorus, and potassium, justifying its use in the treatment and prevention of anaemia and bone disorders[17]. Its amino acid composition is characterised by lysine, leucine, and phenylalanine, but low in methionine and tryptophan[18].

5.2 Secondary Metabolites in Whole Seed and Seed Coat

The bioactivity of horse gram is attributed to its high content of secondary metabolites. The seed coat contains higher levels of phenolic acids such as caffeic, ferulic, vanillic, and p-coumaric acids, and flavonoids such as quercetin, kaempferol, apigenin, and luteolin[19]. They

Table 2. Common names of Horse gram in different Indian languages and their traditional uses

Language	Name	Usage Contexts (Folk medicine and Cuisine)
Hindi	*Kulthi / Kulath*	Used in decoction for kidney stones, cough, and cold; eaten as dal and sprouts.
Sanskrit	*Kulattha*	Mentioned in Ayurveda for *mutrakrichha* (urinary calculi), obesity, and piles; recommended as a medicinal pulse.
Tamil	*Kollu*	Consumed as *rasam* (soup) for colds and weight management; a folk remedy for fever and asthma.
Telugu	*Ulavalu*	Used in traditional dishes (*ulavacharu*) and for joint pain relief in folk practices.
Kannada	*Huruli*	Prepared as curry, horse gram chutney; decoction taken for kidney ailments and digestive issues.
Malayalam	*Muthira*	Consumed as sprouted salad or curry, a folk practice for controlling cholesterol and diabetes.
Marathi	*Kulith*	Traditional "*pithla*" (curry) is prepared; also used as animal feed and for kidney stone remedies.
Gujarati	*Kulith / Kalthi*	Decoctions are used for urinary problems; seeds are consumed as dal during winter.
Bengali	*Kulthi*	Less common in cuisine; used in folk decoctions for kidney ailments and body heating in cold climates.
Odia	*Kolatha*	Prepared as dal and curry; folk medicine for cough and urinary calculi.
Punjabi	*Kulthi*	Decoction used for kidney stones and arthritis; seeds roasted and eaten for warmth in winter.

are accountable for antioxidant, anti-inflammatory, and enzyme inhibition activities. Condensed tannins, although antinutritional, have been discovered to undertake increasingly recognised health functions like lipid metabolism modulation and antimicrobial activity[20]. Isoflavones, saponins, and phytosterols have also been documented, and these have been observed to provide pharmacological importance under conditions of metabolic disorder and cardiovascular health[21]. Interestingly, the higher the phenolic content is in the seed coat than in the cotyledon puts emphasis on processing techniques that retain husk fractions.

5.3 Influence of Environment and Processing on Composition

Agro-climatic heterogeneity highly impacts the overall chemical content of horse gram. Studies have demonstrated that genotypes grown in semi-arid and dryland conditions possess higher protein and overall polyphenol content than humid-grown ones[22]. There are also differences in seed coat thickness and phenolic content in South Indian and Himalayan foothill ecotypes, suggesting adaptability and nutritional versatilities[23]. Processing techniques have a great impact on phytochemical and nutritional components. Germination increases the total phenolic and flavonoid compounds by activating hydrolytic enzymes, thus enhancing antioxidant activity[24]. Fermentation increases the availability of amino acids and reduces phytic acid, tannins, and trypsin activity. Thermal processing, such as roasting and boiling, improves organoleptic properties and digestibility but reduces heat-sensitive compounds like vitamin C and flavonoids[25]. Modern technology, such as extrusion cooking, has been demonstrated to enhance resistant starch and soluble dietary fibre, which can be applied in the production of functional foods[26].

6. Nutritional and Pharmacological Implications

The combination of primary nutrients (proteins, fibres, minerals) and secondary metabolites (polyphenols, flavonoids, saponins) puts horse gram at the crossroads of food and medicine. Its nutrient profile suggests dietary management of malnutrition, while its phytochemicals underpin pharmacological activities including antiurolithiatic, antidiabetic, lipid-lowering, and anti-inflammatory activities. Environmental stress tolerance and post-harvest processing also open up its horizon in food innovation and nutraceutical applications.

7. Active Constituents

Horse gram (*Macrotyloma uniflorum*) is a source of varied bioactive constituents that are responsible for its nutritional and medicinal value, as shown in Table 3. The seed and seed coat contain various classes of primary and secondary metabolites, each with its pharmacological contribution.

7.1 Phenolics, Flavonoids, Saponins, Phytic Acid, Dietary Fibre

Horse gram seed coat is rich in phenolic acids like gallic, ferulic, caffeic, and p-coumaric, providing high antioxidant activity[27]. Flavonoids like quercetin, luteolin, apigenin, and kaempferol provide anti-inflammatory, anti-diabetic, and lipid-lowering activities[28]. Saponins relate to decreased cholesterol and enhanced bile acid metabolism, whereas tannins exert action via inhibition of enzymes. Phytic acid, although classed as an antinutrient, exhibits antioxidant and anticancer effects when taken in moderation[29]. Dietary fibre in horse gram is also high in soluble fractions like β-glucans that contribute to postprandial glycaemic control and enhance colonic health[30].

7.2 Mineral Profile and Bioavailability Aspects

Water soaking of horse gram seeds leads to rich levels of calcium, iron, phosphorus, potassium, and molybdenum, where the levels of iron and calcium can be higher in comparison to other pulses[31]. Their bioavailability is influenced by the presence or absence of antinutritional factors such as phytates, oxalates, and tannins. The processing methods like soaking, sprouting, and fermentation have the potential to significantly increase mineral bioavailability by reducing phytate and increasing enzymatic degradation of complex carbohydrates[32]. Germination has also been shown to improve bio accessible zinc and iron in horse gram-based diets and is thus suitable for managing hidden hunger among rural people[33].

Table 3. Pharmacological activities, mechanisms, and key constituents of Horse gram

Activity	Mechanism of Action	Key Constituents	Plant Part
Antiurolithiatic	Inhibits nucleation, aggregation and growth of calcium oxalate crystals; diuretic effect.	Phenolic acids, flavonoids, saponins	Seeds, seed coat
Antidiabetic	α-amylase and α-glucosidase inhibition; improves postprandial glycaemic control	Flavonoids (quercetin, luteolin), dietary fibre	Seeds, germinated seeds
Anti-obesity	Modulates lipid metabolism; reduces serum cholesterol and triglycerides	Tannins, saponins, and resistant starch	Seeds, seed flour
Antioxidant	Scavenges free radicals; reduces oxidative stress	Polyphenols, flavonoids, phenolic acids	Seed coat, whole seed
Anti-inflammatory	Downregulates cytokines; inhibits COX pathways	Flavonoids, isoflavones	Whole seed extracts
Antimicrobial	Disrupts microbial cell wall integrity; inhibits growth of bacteria/fungi	Phenolic acids, flavonoids, phytosterols	Seed coat, methanolic extract
Cardioprotective	Lowers LDL, increases HDL; antioxidant protection to the myocardium	Flavonoids, dietary fibre, saponins	Seeds
Hepatoprotective	Reduces oxidative liver damage; enhances detoxification enzymes	Phenolics, flavonoids	Ethanolic seed extracts
Nephroprotective	Diuretic effect: reduces renal oxidative damage	Saponins, flavonoids, polyphenols	Aqueous seed extract

8. Extract Types Described in Literature

Various extract types have been used to examine the active constituents and their pharmacological activity. Aqueous and ethanolic seed extracts are widely reported for their antiurolithiatic, hepatoprotective, and antidiabetic activities[34]. Hydroalcoholic seed coat extracts possess strong antioxidant and enzyme inhibitory activity owing to the phenolic enrichment[35]. Methanolic extracts have been employed to assess antimicrobial and anti-obesity activity, whereas germinated seed extracts exhibit increased flavonoid content and radical scavenging activity[36]. These reports signify that the solvent system and processing conditions impact the yield and concentration of bioactive compounds, and thereby their biological activity. In total, horse gram is a legume that is underexploited in that the combination of phenolics, flavonoids, saponins, dietary fibre, and mineral content creates a strong rationale for its classification as a functional food and a potential candidate for therapeutic uses.

9. Different Horse Gram Plant Parts and Pharmacological Uses

The seed and seed coat of horse gram are the richest dietary sources of phytochemicals, of which phenolics, flavonoids, and dietary fibre are most abundant. Seed coat extracts contain greater antioxidant and antimicrobial activity compared to cotyledons, and aqueous and ethanolic seed extracts have been proven for antiurolithiatic and hypoglycaemic activity in experimental models[37,38]. Seed flour interventions also reveal advantages in managing hyperlipidaemia and obesity[39]. Aside from seeds, the leaves and the aerial part are being increasingly investigated. Leaf extracts are rich in antioxidant and wound-healing activity from flavonoids and sterols, and they can be utilised as additional fodder with high digestibility[40,41]. Hulls, sprouts, and processed fractions provide additional value. Hulls, although regarded as by-products, are a good source of insoluble fibre and phenolic acids with hypolipidemic activity[42]. Sprouted seeds exhibit higher flavonoid recovery, α-amylase inhibition, and enhanced bioavailability of minerals, and thus may be applied against diabetes and concealed hunger[43]. Fermented fractions decrease antinutritional components and improve protein digestibility[44]. Overall, various plant parts make horse gram a multifunctional legume with possibilities beyond seeds, illustrated in Figure 2.

10. Ethnobotany and *Ayurvedic* References of *Kulthi*

Horse gram (*Macrotyloma uniflorum*), commonly referred to as *Kulthi* or *Kulattha*, has been repeatedly

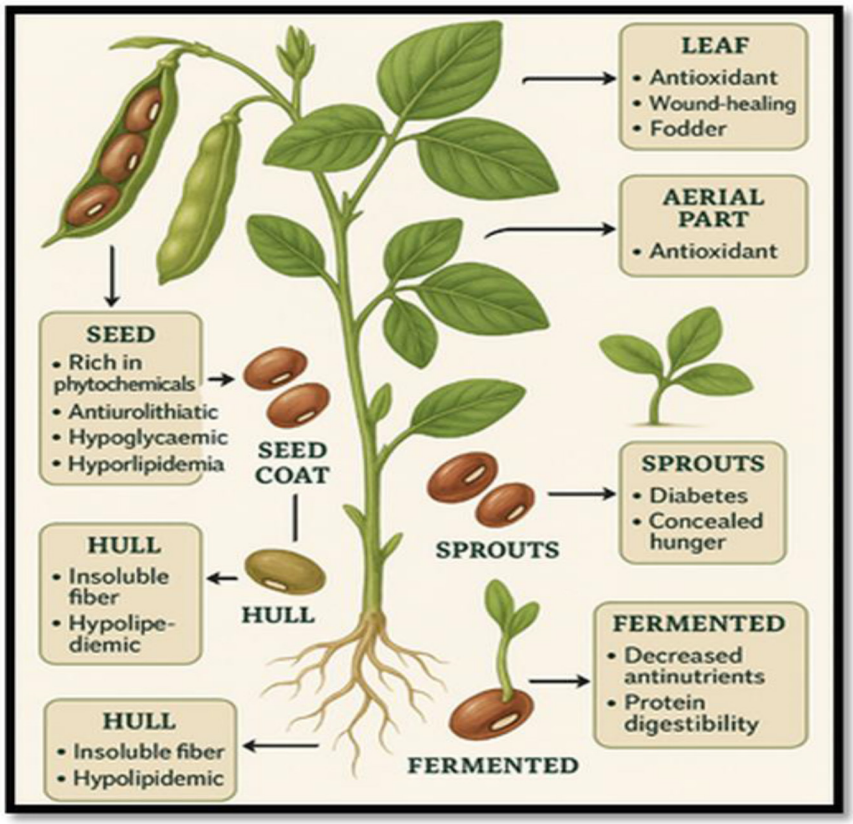


Figure 2. Pharmacological uses of Horse gram plant parts.

reported in ethnobotanical field surveys and traditional *Ayurvedic* literature as a pulse with particular therapeutic functions. In *Ayurvedic* texts like *Charaka Samhita* and *Sushruta Samhita*, *Kulthi* is classified under "*shamidhanya*" (minor legumes) and used for the treatment of *mutrakrichha* (urinary diseases) and *ashmari* (urinary stones) due to its diuretic and litholytic properties[45]. The *Bhavaprakasha Nighantu* also mentions its *ruksha* (dry), *tikta* (bitter), and *kashaya* (astringent) qualities, which render it capable of lowering *meda dhatu* (adipose tissue) and useful in conditions like obesity and stiffness of the joints[46].

In home medicine, *Kulthi* is usually processed as decoctions, soups, or gruel. Decoctions (*kulatthadikwatha*) are recommended for renal calculi and generally consumed two times a day in lukewarm consistency[47]. In North India, less spicy and oily *kulthi* dal is recommended for arthritis, whereas in South India, *ulavacharu*, fermented horse gram soup, is taken for respiratory obstruction and fever[48]. These preparations indicate both dietary and therapeutic functions. Moderate use of horse gram is advocated by *Ayurvedic* texts due to its *rukshaguna*, which can further intensify *vata dosha* if consumed in excess[49]. Ancient warnings point to risks for hyperacidity patients or starvation subjects since frequent consumption can enhance dryness and weakness[50]. Ethnobotanical questionnaire studies in Uttarakhand also record limited use in lactation and pregnancy, demonstrating cultural safety awareness[51]. Combined, folk usage and *Ayurveda* depict *Kulthi* as a diuretic, lithotriptic, and anti-obesity drug, yet acknowledge its limits of safe practice as shown in Table 4.

11. Nutritional Composition and Phytochemistry of Seed and Seed Coat

Horse gram (*Macrotyloma uniflorum*) seeds have a high content of phytochemicals and nutrients. Seeds contain 22–28% protein, in the form of mainly albumins and globulins, 55–60% carbohydrate, and 1–3% fat[52]. Amino acids, including lysine, leucine, and phenylalanine, exist, although, like all legumes, it does not contain

Table 4. Ethnobotanical and Ayurvedic insights on *Kulthi*

Source	Practice	Preparation Mode	Contraindications
Tribal communities (Odisha, Jharkhand)	Avoided in monsoon as it is believed to worsen joint pain	Dietary restriction (no dal in humid season)	Seasonal ethnomedicine taboo[47]
Karnataka folk rituals	Consumed with jaggery for warmth and stamina during festivals	Roasted seeds mixed with jaggery	Reflects cultural-ritualistic significance[48]
Veterinary ethnomedicine (Andhra Pradesh)	Decoction used for urinary blockage in cattle	Boiled seed water given orally	Cross-domain application in animal health[47]
Bhaishajya Ratnavali (Ayurvedic text)	*Kulatthadi churna* recommended for obesity and urinary stones	Powder taken with honey or warm water	Distinct from decoction, focuses on dry formulation[81]
Kumaon Himalaya post-partum diet	Restricted after childbirth due to belief of delayed lactation	Exclusion from daily dal	Ethnobotanical cautionary note[51]

sulphur amino acids and needs complementation with cereals[53]. Seeds also contain soluble and insoluble fibre that contribute to glycaemic control and satiety.

The seed coat contains phenolic acids such as caffeic, ferulic, and p-coumaric acids and flavonoids quercetin and apigenin, which impart high antioxidant activity[54]. These secondary metabolites assist in enzyme inhibition and free radical scavenging but exist alongside antinutrients like tannins, phytic acid, and trypsin inhibitors[55]. Soaking, sprouting, and fermentation are conventional processing techniques that help lower antinutrients, while increasing the bioavailability of minerals and digestibility of proteins[56].

Comparatively, horse gram is richer in iron and calcium compared to chickpea and pigeon pea and has greater polyphenol content than lentil and green gram[57]. Its protein quality is also better than that of small millets, although the millets have superior starch digestibility[58]. Combined, the nutrient and phytochemical composition render horse gram a food security crop with high potential as a functional food (Table 5).

12. Therapeutic Properties Overview

The therapeutic profile of horse gram (*Macrotyloma uniflorum*) has been outlined in the metabolic, renal, and cardiovascular conditions. Antiurolithiatic action has substantial evidence, in which aqueous and methanolic extracts arrest calcium oxalate nucleation and crystal agglomeration in rats as well as in cell culture-based models[59,60]. Such actions comply with its conventional application in *ashmari* management. Antidiabetic activity is aided by *in vitro* and animal evidence, showing α-amylase and α-glucosidase inhibition, enhanced glycaemic control, and modification of hepatic glucose enzymes[61,62]. Anti-obesity action has moderate support, especially from high-fat diet-induced rat models, where supplementation lowered visceral adiposity and serum triglycerides[63]. Likewise, antioxidant and anti-inflammatory effects are routinely found and caused by seed coat polyphenols and flavonoids to reduce cytokines and shield cellular membranes[64,65]. Cardio-protective activities have been found in model studies with enhanced lipid correlations and myocardial enzyme stabilization[66]. Hepatoprotective and nephroprotective activity is also observed, but is still preliminary and mostly depends on rodent assays[67]. From the strength of evidence aspect, antiurolithiatic and antidiabetic properties are strong, antioxidant and anti-inflammatory moderate, with obesity, cardio-hepatic, and nephroprotective assertions being preliminary. There is a lack of translational trials, which limits clinical grading. On safety, acute and sub-chronic toxicity tests in rodents show no unfavourable effects at dietary doses[68]. But elevated tannin and phytic acid content decreases protein digestibility, which highlights the importance of processing methods such as germination and fermentation[69]. Ethnobotanical reports also advise against inappropriate use during pregnancy because of its perceived emmenagogue action[70]. Therefore, horse gram is generally safe, but dose, preparation, and context will have to regulate its therapeutic application.

Table 5. Comparative nutritional and phytochemical profile of horse gram and selected pulses/millets

Pulse/Millet	Protein (%)	Iron (mg/100 g)	Calcium (mg/100 g)	Total Polyphenols (mg GAE/100 g)	Unique Traits
Horse gram (*Macrotyloma uniflorum*)	22–28	7–9	250–300	400–500	High in phenolic acids, strong antioxidant and antiurolithiatic activity
Chickpea (*Cicer arietinum*)	19–21	4–6	150–180	150–200	Good protein quality, lower in polyphenols
Lentil (*Lens culinaris*)	24–26	6–7	70–80	200–250	High protein, moderate polyphenols, better digestibility
Pigeon pea (*Cajanus cajan*)	20–22	5–6	130–150	180–220	Common dal, moderate iron and calcium
Finger millet (*Eleusine coracana*)	6–8	3–4	330–350	100–150	Superior calcium but low protein
Foxtail millet (*Setaria italica*)	11–12	2–3	30–40	80–100	Light cereal, low iron and calcium compared to legumes

13. Pharmacological Actions in Urolithiasis and Metabolic Disorders

13.1 Clinical and Preclinical Scenario

Horse gram (*Macrotyloma uniflorum*) is now a validated ethno-medicinal pulse with proven efficacy against urinary stone disease and metabolic disorders. Experimental nephrolithiasis is reduced by extracts that suppress calcium oxalate (CaOx) crystallisation and deposition, restore renal antioxidant mechanisms, and preserve tubular integrity[71]. Comparative bio-assays reveal horse gram to have greater anti-crystallisation activity compared to various other pulses, demarcating its distinct phytochemical profile[72]. Limited human evidence, including dietary intervention with horse gram soup, reveals weak diuretic and low-glycaemic activity supporting indirectly stone and metabolic risk prevention[73].

13.2 Quality Appraisal of Studies

Most research is adequately designed with respect to biochemical and histological readouts, but is incomplete. Extract preparation is not standardised, dosing varies widely, and models for long-term studies are limited. Blinded histopathology is rare in reports, although when it occurs, it improves reliability[74]. Therefore, evidence of antiurolithiatic activity can be ranked moderate-to-strong, but metabolic endpoints await confirmation with formal structured clinical trials.

13.3 Translational Potential and Limitations

Mechanistically, horse gram polyphenols, saponins, and flavonoids have multi-targeted actions, urinary calcium chelation, increased excretion of citrate, and reduction of renal oxidative damage[75]. The mechanisms fall in line with traditional pharmacological strategies in the prevention of stones, lending greater translational applicability. Nevertheless, lack of standardised products, small numbers, and no dose–response curves limit clinical potential[76].

13.4 Antiurolithiasis

In vitro assays, including gel diffusion and turbidimetric methods, validate that aqueous, methanolic, and phenolic fractions prevent CaOx nucleation and aggregation[77]. Furthermore, ultrasound-assisted extraction increases phenolic release and results in more potent inhibition, while seed-coat extracts typically demonstrate higher inhibitory activity than cotyledons[78].

In vivo ethylene glycol and ammonium oxalate models show that Ethylene glycol-treated rats have hyperoxaluria and CaOx deposition, but the co-treatment with horse gram decreases stone weight and number quite effectively. Protective effects involve enhanced urine flow, reduced urinary calcium/oxalate, and decreased renal retention of CaOx[79]. Ammonium oxalate models also show decreased renal oxidative stress, which corroborates antioxidant-related nephroprotection[80].

Impact on promoters and inhibitors of stone development: Horse gram treatment increases urinary magnesium and citrate, endogenous inhibitors of CaOx precipitation, and decreases excretion of calcium and oxalate[81]. Some studies also indicate decreased urinary uric acid, implying comprehensive effects on lithogenic environment[82].

Histopathology and renal protection endpoints: Histopathological studies demonstrate that treated animals maintain intact glomeruli and tubular epithelia with minimal interstitial inflammation, in contrast to necrosis and dilatation in controls that are not treated[83]. Saponin-rich fractions specifically reverse epithelial desquamation and interstitial fibrosis[84]. The normalisation of renal antioxidant enzymes (SOD, CAT, GPx) also supports nephroprotective efficacy[85].

Together, antiurolithiasis action of horse gram is buttressed by convergent findings from *in vitro* crystallisation tests, *in vivo* models, and mechanism markers. Although *Ayurvedic* writings highlight its litholytic and diuretic activities, recent evidence points to an expanded renal protective effect exerted through oxidative, inflammatory, and metabolic mechanisms.

13.5 Anti-obesity and Antidiabetic Effects of Horse

Horse gram is known as a pulse that has the potential to be used to manage obesity and diabetes because of the high nutritional content and biological activity contained in the pulses. This is because of its high contents of dietary fibre, phenolics, flavonoids, and antioxidants, which regulate glucose and lipid metabolism. Consumption of horse gram regularly might help people lower their body weight and fat deposits by regulating satiety and reducing the rate of carbohydrate digestion. Horse gram will also help in lowering blood sugar levels after meals due to the inhibition of carbohydrate digestive enzymes. Research has shown that horse gram possesses the ability to increase insulin sensitivity and lower serum cholesterol and triglyceride levels.

13.6 Glycaemic Regulation Indicators and Lipid Modulation

Preclinical investigations establish that horse gram enhances several glycaemic and lipid parameters. Seed flour supplementation in alloxan-induced diabetic rats remarkably reduced fasting blood glucose, glycated haemoglobin (HbA1c), and plasma triglycerides and increased HDL cholesterol[86]. Comparable effects have been reported in hyperlipidaemia models, wherein horse gram protein isolates enhanced lipid removal and alleviated hepatic fat accumulation[87]. This indicates its application as a functional dietary supplement for metabolic syndrome.

13.7 Enzyme Inhibition: α-Amylase and α-Glucosidase

Phenolic extracts of horse gram show significant inhibition of carbohydrate digestive enzymes. *In vitro* experiments revealed dose-dependent inhibition of α-amylase and α-glucosidase, the activity being close to that of reference acarbose[88]. Germination increased inhibitory activity because of higher release of flavonoids, notably luteolin derivatives[89]. Such evidence upholds the use of minimally processed preparations of horse gram for glycaemic control.

13.8 Gut Microbiota and Satiety Hypotheses

Horse gram contains abundant resistant starch and fermentable fibre, potentially affecting microbial ecology and satiety. Experimental rat feeding evidenced higher levels of *Bifidobacterium* and *Lactobacillus* species, correlated with greater cecal short-chain fatty acids controlling appetite and insulin sensitivity[90]. Concurrently, *in silico* docking experiments proposed seed polyphenol interactions with gut hormone receptors, presenting hypotheses for satiety modulation[91].

13.9 Human Dietary Intervention Snapshots

Human studies, while limited, offer corroborative evidence. A crossover trial among South Indian adults showed that the addition of horse gram porridge to breakfast food lowered post-prandial glucose excursions versus rice porridge[92]. A further diet survey in rural groups showed regular horse gram consumption was inversely correlated with waist circumference and reported diabetes prevalence[93]. While preliminary studies suggest translational potential.

14. Anti-inflammatory and Antioxidant Activities of Horse Gram

14.1 Oxidative Stress Biomarkers and Antioxidant Capacity

Seed coat and horse gram seeds are rich in flavonoids, phenolics, and tannins that are responsible for high antioxidant capacity. *In vitro* assays have demonstrated great radical scavenging activity with DPPH, ABTS, and FRAP assays, with frequent scores higher than traditional pulses such as mung bean and chickpea[94]. Germination also increases antioxidant potential through increased phenolic acid release and enzymatic antioxidant activity[95]. Animal experiments confirm the restoration of antioxidant biomarkers like superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) in oxidative stress–induced models of horse gram fractions[96].

14.2 Cytokine Modulation and Inflammatory Pathways

Experimental findings show anti-inflammatory activity through modulation of cytokine cascades. Ethanolic seed extracts inhibited TNF-α, IL-1β, and IL-6 concentrations in carrageenan-induced paw oedema and fructose-fed rat models, signifying NF-κB mediated signalling inhibition[97]. Seed coat polyphenols decreased COX-2 expression as well as nitric oxide production in macrophage cultures, demonstrating immunomodulatory potential[98].

14.3 Synergy with Dietary Fibres and Polyphenols

Horse gram fibre matrix of dietary fibre synergistically acts with phenolic compounds to modulate oxidative and inflammatory processes. Bile acid binding insoluble fibres reduce lipid peroxidation, while soluble fractions are fermented to SCFAs that suppress pro-inflammatory mediators[99]. Polyphenols like quercetin and luteolin associate with such fibres, promoting colonic delivery and bioactivity[100]. Collectively, this synergy places horse gram as a legume with special nutraceutical value in oxidative stress and chronic inflammatory disorders.

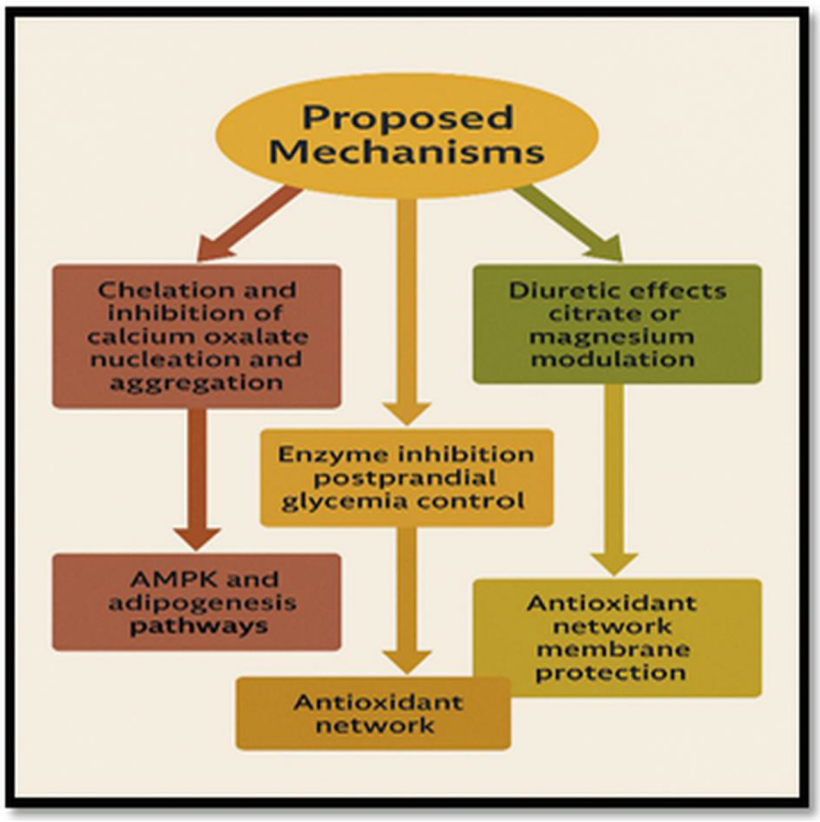


Figure 3. Proposed mechanisms of Horse gram bioactivity in urolithiasis and metabolic disorders.

15. Mechanisms of Action

15.1 Chelation and Inhibition of Nucleation and Aggregation of Calcium Oxalate

Seeds and seed coat phenolics of horse gram are catechol- and galloyl-type motifs, which can chelate calcium and adsorb on nascent crystal faces. This suppresses heterogeneous nucleation, slows aggregation, and induces less adherent crystal habits. These mechanisms are consonant with findings from underutilised Indian legume panels like horse gram, in which elevated total phenolics were associated with strong antioxidant and anti-crystallisation activity *in vitro*[101,102]. At the pathophysiological level, inhibition of urinary supersaturation and alteration of crystal surface charge are complementary to known dietary means of stone prevention[103,104].

15.1.1 Biophysical Mechanism of Calcium Oxalate Crystal Formation and Inhibition

Stone formation due to calcium oxalate involves various steps, including urinary supersaturation, crystal nucleation, aggregation, growth, and attachment to the renal tubular epithelium. The formation of crystals occurs when the levels of calcium and oxalate ions surpass their solubility limits; thereafter, the aggregates increase in size to produce stones. Oxidative stress leads to damage of renal tubular membranes, making adhesion more likely and facilitating the attachment of crystals. The bioactive compounds present in horse gram are expected to inhibit crystallisation through several physicochemical mechanisms. For instance, polyphenols, due to their presence of hydroxyl and carboxyl functional groups, can chelate free calcium ions in solution, thus decreasing their concentrations for nucleation reactions to take place. Additionally, the adsorption of phenolic compounds on crystal surfaces may affect surface charge as well as modify crystal structure, preventing crystal aggregation and minimising interaction between two crystals. Furthermore, antioxidants in horse gram protect against damage caused by oxidative stress in renal tubules, thus making it difficult for crystals to adhere to the membranes.

15.2 Diuretic Effects and Citrate or Magnesium Modulation

Dietary habits that have the effect of increasing urine volume and elevating urinary citrate or magnesium are protective since citrate complexes calcium and magnesium, inhibiting calcium oxalate formation. Botanical diuretics and citrate enhancers thus diminish stone risk in concert with chelation at the crystal interface[105,106]. The legume's fibre and potassium content also contribute to mild natriuretic and alkali load, which are consistent with increased urinary citrate reported for legume-forward diets[107].

15.3 Control of Enzyme Inhibition and Postprandial Glycaemia

Legume phenolic acids and flavonoids occupy the active site of digestive enzymes and slow down the rate of hydrolysis of starch. Structure–activity work indicates that quercetin, luteolin, and caffeic acid derivatives inhibit α-amylase and α-glucosidase concentration dependently, providing a biochemical rationale for reduced postprandial excursions when legume ingredients are consumed in meals[108,109]. Uptake that enhances extractable phenolics, say germination or ultrasound-assisted extraction, may enhance this effect and account for greater activity observed with seed coat–centred preparations[110]. Figure 3 shows the proposed mechanism of horse gram.

15.4 Reported AMPK and Adipogenesis Pathways

Downstream of enhanced glycaemic management, polyphenols have been shown to activate AMP-activated protein kinase in liver and adipose tissue. AMPK activation induces glucose uptake, fatty acid oxidation, and inhibits lipogenesis, along with inhibiting adipogenesis by impaired PPARγ and CEBPα signalling. While direct AMPK assays using horse gram are limited, the prevalent flavonoids identified within this legume are well-characterised AMPK modulators within cell and animal models, rendering this a reasonable translational route for its anti-obesity and antidiabetic effects[111,109].

15.5 Antioxidant Network and Membrane Protection

Oxalate stress in renal epithelia produces reactive oxygen species that enhance retention and adhesion of crystals. Density that is high in horse gram facilitates hydrogen atom transfer and single electron transfer mechanisms, replenishes non-enzymatic antioxidants, and maintains enzymatic defences like superoxide

dismutase, catalase, and glutathione peroxidase, as demonstrated for legume phenolic matrices containing horse gram[112]. Antioxidant defence stabilises membranes, decreases lipid peroxidation, and inhibits pro-inflammatory signalling that would otherwise enhance papillary crystal anchoring[103,105]. A second synergy develops from the concomitant presence of fermentable fibre and polyphenols. Fibre retards starch digestion and transfers substrates to the colon, where microbes create short-chain fatty acids that enhance insulin sensitivity and regulate appetite hormones. These metabolites also have anti-inflammatory actions that decrease systemic oxidative load and indirectly reduce lithogenic stress[113,114]. In intact food form, the synergistic activities of fibres and polyphenols often are greater than the sum of single compounds, facilitating a food-as-medicine approach to horse gram in the prevention of stones and metabolic management[115].

16. Experimental Evidence Summary

Horse gram has therapeutic action through interlinked mechanisms acting on both renal stone formation and metabolic dysregulation. Phenolic acids and flavonoids contained in the seed coat chelate urinary calcium and change the surface charge of nascent crystals, thus slowing calcium oxalate nucleation and aggregation. Laboratory crystallisation assays affirm that seed coat fractions substantially curtail crystal size and count, making clear a direct litholytic role[116]. Supplementation in animal models augmented urinary output, alongside citrate and magnesium excretion, which are two endogenous stone growth inhibitors, proposing a protective effect attributed to diuresis[117]. Metabolic control is partly achieved by enzyme inhibition. Polyphenols like quercetin and luteolin are bound to carbohydrate-digesting enzymes, suppressing α-amylase and α-glucosidase activity, and consequently decreasing postprandial glucose peaks[118]. These effects in obese and diabetic rodent models equated to enhanced glycaemic control and lowered serum triglycerides, accompanied by simultaneous rises in HDL cholesterol[119]. *In vitro* adipocyte culture evidence also indicates that bioactive compounds within horse gram trigger the activation of AMP-activated protein kinase, enhancing fatty acid oxidation and inhibiting adipogenesis[120]. The antioxidant matrix offers a further protective layer. Elevated polyphenol levels scavenge reactive oxygen species, restore catalase and superoxide dismutase activity, and stabilise lipid membranes, diminishing oxidative damage associated with renal epithelial damage and insulin resistance. Together, these highlight the synergy between dietary fibres and phytochemicals, positioning horse gram as a food-based therapeutic agent for urolithiasis and metabolic disorders.

17. Agronomy and Post-harvest for Functional Quality

Horse gram has agronomic vigour and quality functionality that are predominantly conditioned by variety choice, cultivation, environmental conditions, as well as post-harvest care. Himalayan and semi-arid types are shown in comparative studies to contain greater protein and polyphenol accumulation, which shows that environmental stress enhances nutraceutical traits[121,122]. Agronomic management such as low-input organic manuring and millet intercropping has been linked to increased phenolic productivity and mineral content[123,124]. Processing of the post-harvested material is also important, as defueling helps retain seed coat fractions rich in phenolics, whereas roasting improves palatability despite the possible degradation of heat-labile antioxidants[125]. Conventional soaking helps decrease antinutrients like phytic acid and tannins, thus improving the bioavailability of minerals[126]. Germination is the most effective method, which maximises flavonoids, antioxidant potential, and enzyme inhibition activity, thus making sprouted horse gram an ideal functional food matrix[127,128]. Recent advances in the value addition of horse gram include the production of extruded snacks, instant mixes, and blended flours, which help incorporate horse gram into modern eating habits without affecting its bioactive compounds[129]. Agronomy–quality links of prime importance are:

i. Varietal and ecotype choices set the baseline phytochemical density.
ii. Stress-adapted growing increases antioxidant activity.
iii. Post-harvest processing (soaking, germination, roasting) affects the bioavailability of nutrients.
iv. Extruded snack foods, flours, and porridges expand their uses.

In combination, these initiatives highlight the promise of horse gram as a climate-resilient crop and as a functional food ingredient in preventive healthcare.

18. Conclusion

Horse gram (*Macrotyloma uniflorum*) is a less-appreciated but promising legume with immense nutritional and medicinal potential. The evidence available reveals its efficacy in addressing malnutrition and increasingly common metabolic and renal disorders. It is rich in protein, minerals, and diverse phytochemicals, which can significantly enhance food security and functional medicine. In traditional medicine, particularly in *Ayurvedic* practices, horse gram has been traditionally used to address urinary stone disorders, obesity, and metabolic disorders. Contemporary research is increasingly validating these traditional practices, establishing their efficacy in inhibiting stone formation, reducing blood sugar levels, combating obesity, and functioning as an antioxidant and anti-inflammatory agent. What was hitherto traditional knowledge is now being explored through biochemical and pharmacological approaches, examining its potential to inhibit crystal formation and enzymes, enhance antioxidants, and activate AMPK. There is also evidence to suggest that processing techniques such as soaking, sprouting, and fermentation can not only preserve but also enhance the bioavailability of its active principles and decrease anti-nutritional factors. This indicates that small, farmer-friendly modifications can significantly enhance the useful properties of the crop. Through the addition of value in terms of functional foods such as flour, porridge, and extruded snacks, horse gram can reach urban markets in a healthy and consumer-friendly manner. The review points out the novel concept of combining the hardness of the legume in terms of its agricultural use with its health-giving properties. The legume is drought-resistant in its agricultural use and possesses numerous bioactive properties, making it a suitable candidate for future cultivation in regions where climate change and more lifestyle-related diseases are common. In terms of policy, the inclusion of horse gram in national nutrition programs, school meal programs, and nutraceutical industries is feasible. In practice, the benefits will be derived by both consumers and farmers through a combination of approaches that focus on stress-tolerant landraces, simple processing, and the addition of the legume to common diets. In research, the highest priorities include human studies, metabolomics, and the preparation of standardised extracts to validate and utilise their therapeutic potential. In conclusion, the future for horse gram is bright. Long-term sustainability will be achieved through the combination of traditional knowledge with modern science. Through a focus on its climate-resilient properties and functional food value, this legume has the potential to contribute to the reduction of disease and the support of small farmers. The realisation of this potential will require collaboration between agronomists, food scientists, and pharmacologists to make horse gram a central part of sustainable nutrition and health.

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Author Contribution

M.N. conceptualized the review, performed literature collection, data interpretation, and drafted the manuscript. B.B. and A.P. contributed to manuscript structuring, critical reviewing, and technical corrections. A.Pa., D.N., and N.S. assisted in literature survey and compilation of scientific information. S.S. and J. contributed to editing, formatting, and reference management. R.K., S.K.P., and S.Sa. participated in data organization, visualization, and manuscript improvement. A.P. and H.K. supervised the overall study, reviewed the manuscript critically, and approved the final version for publication. All authors have read and agreed to the published version of the manuscript.