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A comprehensive review on harnessing the potential of Indian under-exploited legumes for nutritional security

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Abstract

Under-exploited legumes are a rich and varied resource that has the potential to significantly address the global issues pertaining to food security, nutrition, and agricultural sustainability. The nutritional value, bioactive components, pre and probiotic potential, value addition techniques of underutilized legumes are the main topics of this paper that signify the recent research findings and viewpoints. The nutritional qualities of underutilized legumes are dealt with special attention paid to their high protein content, vital amino acids, vitamins, and minerals. These legumes can improve diet, especially in areas where malnutrition is common, as they provide an alternative to traditional sources of protein. To reduce losses, extend shelf life, and boost marketability, an overview of value addition, and processing techniques are considered. Throughout the value chain, optimizing the nutritional and financial advantages of underutilized legumes depends on the adoption of suitable post-harvest technologies. To realize the full potential of these legumes, traditional breeding techniques, participatory approaches, and molecular tools are used. This review paper highlights the significance of underutilized legumes strengthening food and nutrition value, diversifying diets, and enhancing agricultural sustainability. This review advocates for targeted research and policy initiatives to elevate the status of underexploited legumes, ensuring their role in future food systems. It also identifies critical research goals to trap the potential of these underutilized legumes.

1. Introduction

Agriculture is under coercion to produce enormous quantities of food, fodder, and biofuel for the growing population by 2050 on the limited land resources for the projected nine billion people as per the UN report. With rapid increase in population and urbanization, it's been a major threat to meet the food supply demand over the globe. The Fabaceae family, also known as Leguminosae, is home to a diverse range of plants known as legumes, which are highly valued for their ecological significance and nutritional content. These plants are a rich source of protein and nutrients, and they play a crucial role in enriching the soil through nitrogen fixation (Singh *et al.*, 2007). Legumes are also economically important, with grain legumes accounting for a significant portion of global crop production and dietary protein consumption (Smýkal *et al.*, 2015).

Legume crops have been cultivated for ages all over the world and have become mainstays in many different culinary traditions. The under-exploited legume crops are a broad range of legumes with valuable features and potential advantages but lack attention or research for study, development, and commercialization are referred

to as underutilized or underexplored legume crops (Samal *et al.*, 2023).

2. Under-exploited legume crops: Opportunities and challenges

2.1 Opportunities

Underexploited legume species harbor a rich genetic bounty that remains largely untapped, presenting a fertile ground for exploring and harnessing a myriad of valuable traits (Jha *et al.*, 2022). Tapping into this genetic wealth could unlock promising avenues for improving legume crop performance, nutritional value, and ecological suitability across diverse agricultural landscapes (Upadhyaya *et al.*, 2011). Numerous underexploited legume crops possess an inherent ability to thrive in adverse environmental conditions, rendering them invaluable assets for developing climate-resilient and sustainable agricultural systems (Mayes *et al.*, 2019).

These legumes present a compelling opportunity to combat nutritional insecurity and dietary monotony by introducing diverse sources of plant-based proteins, essential micronutrients, and beneficial bioactive compounds (Popoola *et al.*, 2019). Harnessing the unique properties and compositions of these underutilized legume crops accelerates exciting opportunities for farmers and entrepreneurs to diversify their product portfolios, explore niche markets, and capitalize on the growing consumer demand for sustainable nutrition (Dhaliwal *et al.*, 2020).

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Table 1: List of under-exploited legumes and their uses

S.No.	Common name	Scientific name	Centre of origin	Uses	Reference
1.	Winged bean	<i>Psophocarpus tetragonolobus</i> (L.) DC.	Southeast Asia, Africa, and Latin America	Edible pods, leaves, and seeds are rich in protein and vitamins used in Asian cuisines.	Bassal <i>et al.</i> , 2020
2.	Jack bean	<i>Canavalia ensiformis</i> (L.) DC.	Central America	Green manure, animal feed, and seeds are used in traditional medicine.	Kurniawati <i>et al.</i> , 2021
3.	Sword bean	<i>Canavalia gladiata</i> (Jacq.) DC.	Africa, Asia	Edible beans and foliage are used in traditional cuisines.	Wijaya <i>et al.</i> , 2020
4.	Lima bean/butter bean	<i>Phaseolus lunatus</i> (L.)	South America	Consumed as a protein-rich vegetable. Can be dried or canned.	Baudoin, 1993
5.	Hyacinth bean/ Lablab bean	<i>Lablab purpureus</i> (L.)	Africa, Asia	Edible beans and leaves are used as vegetables. Seeds also used as animal feed.	Sonali <i>et al.</i> , 2015
6.	Broad bean	<i>Vicia faba</i> L.	Mediterranean region	Often used in soups, stews, and salads. Seeds can be dried or processed.	Kirk, 2004
7.	Velvet bean/ Lyon bean	<i>Mucuna pruriens</i> (L.) DC.	India	Medicinal (Parkinson's disease treatment), fodder, green manure.	Kavitha <i>et al.</i> , 2020
8.	Negro beans/ deer-eye beans/ donkey-eye beans or ox-eye beans	<i>Mucuna monosperma</i> DC. Ex Wight	India	Seed is astringent to bowels, cardio-tonic, aphrodisiac, and sedative in nature.	Sathyanarayana <i>et al.</i> , 2016
9.	Bambara groundnut	<i>Vigna subterranean</i> (L.) Verdc	West Africa	Nutritious food source, high in protein and micronutrients.	Chandra <i>et al.</i> , 2019
10.	Mung bean	<i>Vigna radiata</i> (L.) Wilczek	Southeast Asia	Highly nutritive food, important feed, and fodder crop.	Dahiya <i>et al.</i> , 2015
11.	Yard long bean	<i>Vigna unguiculata</i> subsp. <i>Sesquipedalis</i> (L.) Verdc	South east Asia	Eaten as a vegetable, often stir-fried or used in salads.	George <i>et al.</i> , 2022
12.	Adzuki bean	<i>Vigna angularis</i> (Willd.) Ohwi & H. Ohashi	East Asia, Himalayan region	Commonly used in Asian cuisines for sweet bean paste and desserts.	Li <i>et al.</i> , 2022
13.	Rice bean	<i>Vigna umbellata</i> (Thunb.) Ohwi & H. Ohashi	Southeast Asia, India	Consumed as a nutritious grain in various dishes.	Asha <i>et al.</i> , 2015
14.	Moth bean	<i>Vigna acontifolia</i> (Jacq.) Maréchal	India, Pakistan	Seeds are edible and rich in protein, making them a valuable food source.	Bhadkaria <i>et al.</i> , 2022
15.	Stinky bean	<i>Parkia speciosa</i> Hassk.	Southeast Asia, Malaysia	Pods and seeds are used in various culinary dishes, often fermented.	Kamisah <i>et al.</i> , 2013
16.	African yam bean	<i>Sphenostylis stenocarpa</i> (Hochst. ex A. Rich.) Harms	West Africa	Tubers and seeds used as food; highly nutritious and drought-resistant.	Oagile <i>et al.</i> , 2007
17.	Marama bean/ Gem's book bean	<i>Tylosema esculentum</i> (Burch.) A. Schreib.	Southern Africa, Namibia	Edible seeds are used traditionally, gaining interest in commercial use.	Chimwamurombe 2016
18.	Ground bean or Kersting's groundnut	<i>Macrotyloma geocarpum</i> (Harms) Maréchal and Baudet	Western Africa	Seeds are rich in protein, and healthy fats used to cure fatty liver diseases	Wong <i>et al.</i> , 2005
19.	Yam bean	<i>Pachyrhizus erosus</i> (L.) Urb.	Mexico and northern South America	Seeds are rich in protein and other nutrients used to treat bone diseases.	Melo <i>et al.</i> , 2003
20.	Khejri or tree of paradise	<i>Prosopis cineraria</i> (L.) Druce	Western Asia	Tree has traditional medicinal uses, including treatments for digestive issues and skin ailments.	Meena <i>et al.</i> , 2018

2.2 Challenges of growing underexploited legumes

There is a dearth of improved, high-yielding varieties specifically tailored to thrive across diverse agroecological zones and farming systems, impeding their widespread adoption (Paliwal *et al.*, 2020). In certain regions, underexploited legumes are stigmatized and regarded as “food for the impoverished” or carry negative cultural connotations, hampering their acceptance and consumption among the broader

population, thereby posing a significant barrier to their mainstream integration (Gowda *et al.*, 2006; Dhaliwal *et al.*, 2020). A glaring knowledge gap persists regarding the potential advantages, cultivation methods, and culinary applications of underexploited legumes, which creates substantial hurdles to their widespread adoption (Popoola *et al.*, 2019). This lack of awareness and understanding among farmers, agricultural extension personnel, and consumers contributes to the marginalization of these neglected crops.

Table 2: Obstacles hindering the widespread cultivation of underexploited legumes and its solutions

Obstacles	Solutions
Lack of awareness and consumer demand	Promote culinary diversity by integrating legumes into mainstream diets.
Limited market access and infrastructure	Invest in infrastructure (processing, storage, and transportation) to improve market access.
Inadequate research and development	Establish partnerships between governments, academic institutions, and international organizations.
Limited processing options	Invest in scaling up appropriate processing technologies (e.g., milling, canning, freezing) to create shelf-stable products.
Lack of government support and policy	Implement policies that promote the cultivation of UELs such as subsidies, tax incentives, and technical assistance for farmers.
Lack of trade and export potential	Explore niche export markets, such as organic or specialty health food markets, to build international demand.

Table 3: Nutritional composition of the selected underexploited legumes raw, mature seeds with values per 100 g

Legumes	Water (g)	Protein (g)	Fat (g)	Energy (kcal/100 g)	Vitamin A (mg/100 g)	Calcium (mg/100 g)	Iron (mg/100 g)	Potassium (mg/100 g)
WB	8.34	29.60	16.30	409.0	Nr	440	13.40	977
JB	Nr	20.90	1.59	338.0	Nr	3.21	0.83	5.93
SB	83.6	21.0	0.20	4	Nr	60.0	2.00	180
LB	69.8	7.80	0.38	115	0.00	17.0	2.39	508
HB	87.9	8.2	1.69	344	0.1	40	4.6	1235
BB	11.6	8.00	0.7	88	3	103	6.7	1593
VB	7.86	31.44	6.45	290.7	0.73	104	7.47	1343
NB	Nr	7.3	0.4	132	17.0	123.0	5.0	1483
BG	10.30	18.8	6.20	367.0	Nr	1.60	5.52	183
MGB	Nr	23.80	1.22	344	200	216	6.74	1443
YLB	88.2	2.8	0.40	47	8.65	50	0.47	240
AB	13.4	20.36	0.45	334.8	11.3	66	4.98	1233
RB	Nr	20.50	0.60	318	Na	340	1.6	Na
MB	34.3	23	1.6	343	3.92	150	1.50	1191
STB	77.2	5.4	1.1	92	0.00	14	69.0	221
AYB	61.50	22.46	3.59	333	Nr	15	27.4	419
GBB	Nr	34.71	4.06	544	0.27	241	3.95	0.78
GRB	9.7	19.4	1.1	348	Na	103	15	6.29
YB	Na	1.00	0.1	49	Na	15	0.6	Nr
KJ	18.6	9.4	0.4	311	4.8	38	19	0.3

Values adopted from the United States Department of Agriculture (USDA)

WB: Winged bean (*Psophocarpus tetragonolobus* (L.) DC.), JB: Jack bean (*Canavalia ensiformis* (L.) DC.), SB: Sword bean (*Canavalia gladiata* (Jacq.) DC.), LB: Lima bean (*Phaseolus lunatus* L.), HB: Hyacinth bean (*Labiab purpureus* (L.)), BB: Broad bean (*Vicia faba* L.), VB: Velvet bean (*Mucuna pruriens* (L.) DC.), NB: Negro bean (*Mucuna monosperma* DC. Ex Wight), BG: Bambara groundnut (*Vigna subterranean* (L.) Verdc), MGB: Mung bean (*Vigna radiata* (L.) Wilczek), YLB: Yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis* (L.) Verdc), AB: Adzuki bean (*Vigna angularis* (Willd.) Ohwi & H. Ohashi), RB: Rice bean (*Vigna umbellata* (Thunb.) Ohwi & H. Ohashi), MB: Moth bean (*Vigna acotifolia* (Jacq.) Maréchal), STB: Stinky bean (*Parkia speciosa* Hassk), AYB: African yam bean (*Sphenostylis stenocarpa* (Hochst. ex A. Rich.) Harms), GBB: Gems book bean (*Tylosema esculentum* (Burch.) A. Schreib.), GRB: Ground bean (*Macrotyloma geocarpum* (Harms) Maréchal and Baudet), YB: Yam bean (*Pachyrhizus erosus* (L.) Urb.), KJ: Khejri tree (*Prosopis cineraria* (L.) Druce), Nr: Not reported, Na: Not available.

3. Nutritional and bioactive composition

3.1 Nutritional composition of underexploited legumes

Underexploited legumes, such as sword beans, winged beans, and bambara groundnut, are rich in high-quality proteins (25-30% dry weight), complex carbohydrates, and dietary fiber, making them excellent for improving nutrition and managing blood sugar. They contain essential minerals like iron, calcium, and zinc, as well as B vitamins.

3.2 Bioactive composition of underexploited legumes

Bioactive compounds like antioxidants (polyphenols, flavonoids), phytochemicals (saponins, lectins), and prebiotics promote health benefits such as anti-inflammatory, antimicrobial, and gut health effects. Some legumes, like broad beans, also contain isoflavones with potential anticancer properties. Despite their nutritional value, antinutrients like phytic acid can be reduced through proper processing methods (Popoola *et al.*, 2012).

Table 4: Underexploited legumes bioactive composition and medicinal benefits

S.No.	Legume	Bioactive principle	Chemical formula	Medicinal value	Reference
1.	Winged bean	Tannins, flavonoids	$C_{76}H_{52}O_{46}$	Potential antioxidant, antimicrobial, and anti-inflammatory.	Sharma <i>et al.</i> , 1996
2.	Jack bean	Concanavalin, Canavanine, L-Canaline	$C_{53}H_{82}N_{14}O_{17}$	Therapeutic and health promoting effects include antioxidant, antimicrobial, and immunomodulatory activities.	Bai <i>et al.</i> , 2015
3.	Sword bean	Canavanine (amino acid)	$C_5H_{12}N_2O_2$	Potential antidiabetic and antioxidant effects.	Anitha <i>et al.</i> , 2020
4.	Lima bean/ butter bean	Phaseolamin	$C_{20}H_{18}O_4$	Inhibits alpha-amylase, potentially aiding in weight loss and diabetes management.	García <i>et al.</i> , 2021
5.	Hyacinth bean/ Lablab bean	Tannins, flavonoids	$C_{76}H_{52}O_{46}$	Antioxidant, anti-inflammatory, and antimicrobial properties.	Olawuyi <i>et al.</i> , 2005
6.	Broad bean	L-dopa (levodopa)	$C_9H_{11}NO_4$	Used in Parkinson's disease treatment and as a natural source of dopamine.	Sin <i>et al.</i> , 2024
7.	Velvet bean/ Lyon bean	L-dopa (levodopa)	$C_9H_{11}NO_4$	Used in Parkinson's disease treatment and as a natural source of dopamine.	Kavitha <i>et al.</i> , 2020
8.	Negro beans beans	Flavonoids, Saponins, Phenolics	$C_{15}H_{12}O_2$	Cardioprotective, anti-inflammatory, antioxidant.	Sánchez <i>et al.</i> , 2017
9.	Bambara groundnut	Phenolic compounds	C_6H_5OH	Antioxidant, anti-inflammatory, and potential anticancer properties.	Soumare <i>et al.</i> , 2022
10.	Mung bean	Polyphenols, polysaccharides, peptides	$C_{21}H_{21}O_{11}$	Anti-inflammatory, antioxidant, chronic disease prevention.	Dahiya <i>et al.</i> , 2015 & Lalitha <i>et al.</i> , 2022
11.	Yard long bean	Flavonoids, saponins	$C_{15}H_{12}O_2$	Antioxidant, anti-inflammatory properties, digestive aid.	Devi <i>et al.</i> , 2024
12.	Adzuki bean	Phaseolamin	$C_{20}H_{18}O_{11}$	Inhibits alpha-amylase, potentially aiding in weight loss and diabetes management.	Li <i>et al.</i> , 2022
13.	Rice bean	Flavonoids	$C_{15}H_{12}O_2$	Antioxidant, anti-inflammatory properties.	Munjal <i>et al.</i> , 2024
14.	Moth bean	Phytic acid, phenolics, tannins, lectins.	C_6H_5OH	Antioxidant, anti-inflammatory, cholesterol-lowering effect.	Bhadkaria <i>et al.</i> , 2022
15.	Stinky bean	Alkaloids, flavonoids	$C_{20}H_{21}NO_4$	Antimicrobial, potential anticancer properties.	Kamisah <i>et al.</i> , 2013
16.	African yam bean	Tannins, flavonoids	$C_{76}H_{52}O_{46}$	Antioxidant, antimicrobial, and nutritional benefits.	Oagile <i>et al.</i> , 2007
17.	Marama bean/ Gem's book bean	Phytoestrogens	$C_{30}H_{18}O$	Traditional uses include menopausal relief and nutritional benefits.	Omotayo <i>et al.</i> , 2021
18.	Ground bean or Kersting's groundnut	Phytosterols, flavonoids, saponins	$C_{29}H_{50}O$	Antioxidant, anti-inflammatory.	Ikujenlola <i>et al.</i> , 2022
19.	Yam bean	Flavonoids, inulin, phenolic compounds	$C_{15}H_{12}O_2$	Anti-inflammatory that aids in digestion and cardiovascular health.	Melo <i>et al.</i> , 2003
20.	Khejri or tree of paradise	Prosopisin, flavonoids, tannins	$C_{22}H_{37}NO_7$	Antimicrobial, antioxidant.	Singh <i>et al.</i> , 2023

3.3 Addressing antinutritional factors

While offering a myriad of nutritional virtues, underexploited legumes can also harbor various antinutritional compounds that may undermine their nutritive value and impede digestibility. These compounds encompass protease inhibitors, such as trypsin inhibitors, which can disrupt protein digestion, as well as phytic acid, a compound that binds to minerals, thereby reducing their bioavailability (Dang *et al.*, 2018). Germination of legumes notably increases nutrient content and availability, primarily by reducing anti-nutritional factors through enzyme activation. The anti-nutritional factors can be reduced through cultural methods like selective breeding and improved soil management, physical methods such as soaking, boiling, fermentation, and roasting, and chemical treatments like alkaline soaking and enzymatic degradation, enhancing their nutritional value, digestibility, and market potential (Ayushi *et*

al., 2024). Moreover, certain underexploited legumes such as Winged bean, Sword bean, and Marama bean contain indigestible oligosaccharides like raffinose and stachyose, which can contribute to flatulence, alongside saponins that may interfere with nutrient absorption and cyanogenic glycosides can release toxic hydrogen cyanide (Han and Baik, 2006).

4. Prebiotic and probiotic potential of underexploited legumes

4.1 Prebiotic potential

Underexploited legumes have significant prebiotic potential due to their high fiber content, particularly oligosaccharides like raffinose and stachyose, which resist digestion in the small intestine and reach the colon, stimulating the growth of beneficial gut bacteria.

Table 5: Prebiotic compounds of the selected underexploited legumes and their role in microbial growth

Legume crop	Prebiotic compounds	Beneficial microbial growth	Health benefits	Reference
Winged bean	Stachyose, raffinose, oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i> , <i>Bacteroides</i>	Improves gut microbiota diversity, enhances fermentation, and promotes SCFA production	Bassal <i>et al.</i> , 2020
Jack bean	Raffinose, stachyose, oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i>	Supports gut health, improves digestion, boosts SCFA production	Diakostefani <i>et al.</i> , 2024
Sword bean	Raffinose, stachyose, oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i>	Increases beneficial gut bacteria, enhances SCFAs, reduces inflammation	Tiwari <i>et al.</i> , 2007
Lima bean	Raffinose, stachyose, oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i>	Promotes gut health, supports digestion, improves microbial balance	Lomas-Soria <i>et al.</i> , 2015
Hyacinth bean	Raffinose, stachyose, galactomannans	<i>Bifidobacterium</i> , <i>Lactobacillus</i> , <i>Enterococcus</i>	Enhances gut microbiota diversity, promotes digestion, reduces constipation	Zhou <i>et al.</i> , 2025
Broad bean	Galacto oligosaccharides, raffinose, stachyose	<i>Bifidobacterium</i> , <i>Lactobacillus</i>	Improves gut health, increases SCFA production, boosts digestion	Sin <i>et al.</i> , 2024
Velvet bean	Stachyose, raffinose, oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i>	Promotes gut motility, enhances microbial balance, increases SCFA production	Shinde <i>et al.</i> , 2019
Negro bean	Raffinose, stachyose, oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i> , <i>Bacteroides</i>	Enhances gut microbiota diversity, increases SCFAs	Jha <i>et al.</i> , 2017
Bambara groundnut	Oligosaccharides (raffinose, stachyose), fiber	<i>Bifidobacterium</i> , <i>Lactobacillus</i> , <i>Enterococcus</i>	Improves gut health, enhances digestion, and SCFA production	Yalmancý <i>et al.</i> , 2021
Mung bean	Stachyose, raffinose, fiber, oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i> , <i>Faecalibacterium</i>	Supports gut microbiota, reduces inflammation, improves digestibility	Rani <i>et al.</i> , 2019
Yard long bean	Raffinose, stachyose, galactose oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i>	Enhances gut health, improves fermentation, SCFA production	Gupta <i>et al.</i> , 2020
Adzuki bean	Stachyose, raffinose, fiber	<i>Bifidobacterium</i> , <i>Lactobacillus</i> , <i>Bifidobacterium adolescentis</i>	Enhances gut microbiota diversity, aids in digestion, lowers cholesterol	Li <i>et al.</i> , 2022
Rice bean	Stachyose, raffinose, oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i>	Promotes gut health, increases SCFA production	Munjal <i>et al.</i> , 2024
Moth bean	Raffinose, stachyose, oligosaccharides	<i>Bifidobacterium</i> , <i>Lactobacillus</i>	Enhances gut microbiota, improves digestion, and fermentation	Dakhli <i>et al.</i> , 2021

Stinky bean	Oligosaccharides (raffinose, stachyose)	<i>Bifidobacterium, Lactobacillus</i>	Modulates gut health, enhances fermentation, and production of SCFAs	Kamisah <i>et al.</i> , 2013
African yam bean	Stachyose, raffinose, galactomannans	<i>Bifidobacterium, Lactobacillus, Faecalibacterium</i>	Improves gut microbiota diversity, supports digestion	Oagile <i>et al.</i> , 2007
Marama bean	Oligosaccharides, fiber, galactose	<i>Bifidobacterium, Lactobacillus</i>	Enhances gut flora, increases SCFA production	Alabi, 2023
Groundnut bean	Oligosaccharides, galactose, mannose	<i>Bifidobacterium, Lactobacillus, Bacteroides</i>	Supports gut health, reduces inflammation, boosts immune function	Ghazi <i>et al.</i> , 2018
Yam bean	Stachyose, raffinose, insulin-like oligosaccharides	<i>Bifidobacterium, Lactobacillus</i>	Improves gut health, enhances SCFA production, reduces colonic pH	Melo <i>et al.</i> , 2020
Khejri-pods	Galactomannans, arabinogalactans, oligosaccharides	<i>Bifidobacterium, Lactobacillus, Prevotella</i>	Modulates gut microbiota and increases microbial diversity	Kumar <i>et al.</i> , 2018

Table 6: Probiotic compounds of the selected underexploited legumes and their potential w.r.t health benefits

Legume crop	Probiotic compounds	Probiotic potential	Health benefits	Reference
Winged bean	Rich in oligosaccharides (FOS, GOS), fibers, essential amino acids, antioxidants	Supports the growth of beneficial gut bacteria like <i>Bifidobacterium, Lactobacillus</i> , and <i>Bacteroides</i> .	Enhances gut microbiota diversity, improves digestion and nutrient absorption, and boosts immune function.	Mshelia <i>et al.</i> , 2023
Jack bean	Contains oligosaccharides, resistant starch, peptides, and proteins.	Promotes growth of beneficial bacteria such as <i>Lactobacillus</i> and <i>Bifidobacterium</i> ; potential for LAB fermentation.	Supports gut health by improving gut microbiota composition, potential to improve lactose digestion, and aid in immunity.	Kundu <i>et al.</i> , 1990
Sword bean	Rich in oligosaccharides (including raffinose, and stachyose), protein, and fiber.	Fermented by <i>Lactobacillus</i> and other LAB strains, producing metabolites like lactic acid that support gut health.	May improve gut flora balance and digestion, reduce inflammation, and contributes to metabolic health.	Karmakar <i>et al.</i> , 2024
Lima bean	Rich in oligosaccharides (raffinose, stachyose), fiber, and resistant starch.	Fermentable by <i>Lactobacillus</i> and <i>Bifidobacterium spp.</i> , promoting gut health and reducing gut inflammation.	Improves digestion and bowel regularity, reduces the risk of colon cancer, and boosts immune function.	Yadav <i>et al.</i> , 2018
Hyacinth bean	Contains oligosaccharides (raffinose, stachyose), proteins, and peptides.	Supports growth of <i>Bifidobacterium</i> and <i>Lactobacillus</i> , producing beneficial metabolites during fermentation.	Improves gut microbiota balance, supports heart health, and reduces cholesterol levels.	Wu <i>et al.</i> , 2023
Broad bean	Rich in fiber, oligosaccharides (raffinose, stachyose), and antioxidants.	Fermented by <i>Lactobacillus spp.</i> to produce organic acids that support gut flora.	Supports gut health and immune function, reduces blood sugar levels, antioxidant properties.	Sin <i>et al.</i> , 2024
Velvet bean	High in oligosaccharides, fiber, and L-DOPA (a precursor to dopamine).	Can promote growth of <i>Lactobacillus</i> and <i>Bifidobacterium</i> and may help in managing gut-related disorders.	Improve mood and mental health due to L-DOPA, enhance gut health, and potentially improve bloodsugar.	Kavitha <i>et al.</i> , 2020
Negro bean	Contains oligosaccharides, resistant starch, and fiber.	Supports probiotic growth, especially <i>Bifidobacterium</i> and <i>Lactobacillus</i> , when fermented.	Enhances gut health and microbial balance, reduces inflammation, and improve digestion.	Jha <i>et al.</i> , 2017
Bambara groundnut	Rich in fiber, oligosaccharides, and phenolic compounds.	Ferments well with <i>Lactobacillus spp.</i> , improving gut microbiota and promoting gut health.	Improves digestion and absorption of nutrients, reduce gut inflammation, and support immune health.	Adebo <i>et al.</i> , 2017
Mung bean	Contains oligosaccharides, soluble fiber, and proteins.	Fermentable by <i>Lactobacillus</i> and other LAB, supporting the growth of beneficial gut microbiota.	Supports digestion, nutrient absorption, and improves blood sugar regulation.	Kaur <i>et al.</i> , 2022
Yard long bean	High in oligosaccharides, fiber, and vitamins.	Fermented by <i>Lactobacillus</i> and <i>Bifidobacterium</i> , promoting beneficial bacteria in the gut.	Improves gut health and bowel movement regularity.	Quamruzzaman <i>et al.</i> , 2022

Adzuki bean	Rich in fiber, oligosaccharides (raffinose), and antioxidants.	Fermented by <i>Lactobacillus</i> spp., improving gut flora and aiding digestion.	Helps regulate blood sugar, enhances gut health, and microbial balance.	Padhi <i>et al.</i> , 2023
Rice bean	Contains oligosaccharides (raffinose, stachyose), fiber, and proteins.	Fermented by <i>Lactobacillus</i> and <i>Bifidobacterium</i> , supporting gut microbiota and overall digestion.	Improves gut flora and digestion, reduces cholesterol levels, and supports metabolic health.	Munjal <i>et al.</i> , 2024
Moth bean	Rich in oligosaccharides (raffinose, stachyose), fiber, and protein.	Fermented by <i>Lactobacillus</i> and <i>Bifidobacterium</i> , supports the growth of beneficial gut bacteria, enhancing digestion.	Improves digestion and gut microbiota, reduces the risk of colon cancer, and boosts immune function.	Gupta <i>et al.</i> , 2016
Stinky bean	Contains oligosaccharides, peptides, and proteins.	Supports growth of <i>Lactobacillus</i> and other LAB strains, enhancing gut health and microbiome balance.	Improves gut flora balance, enhances liver, and kidney function.	Kamisah <i>et al.</i> , 2013
African yam bean	Rich in oligosaccharides, fiber, and minerals (e.g., calcium, iron)	Fermentable by <i>Lactobacillus</i> spp., promoting the growth of beneficial gut bacteria and supports gut health.	Enhances gut health, immunity, and reduces risk of chronic diseases.	Olomitutu, 2023
Marama bean	Contains oligosaccharides (raffinose, stachyose), fiber, and proteins.	Can be fermented by <i>Lactobacillus</i> spp. to produce beneficial metabolites such as lactic acid, supporting gut flora balance.	Improves digestion and reduces gut inflammation.	Alabi, 2023
Groundnut bean	High in fiber, oligosaccharides, and healthy fats.	Supports the growth of probiotics like <i>Bifidobacterium</i> and <i>Lactobacillus</i> spp., improving gut health.	Supports immune health, regulates blood sugar, and cholesterol.	Adeoye <i>et al.</i> , 2021
Yam bean	Rich in fiber, oligosaccharides (raffinose, stachyose), and antioxidants.	Fermentable by LAB, promoting growth of beneficial bacteria and the production of organic acids like lactic acid.	Supports gut health, digestion, and reduces inflammation.	Alagbe <i>et al.</i> , 2024
Khejri pods	Contains oligosaccharides, polyphenols, and proteins.	Fermented by <i>Lactobacillus</i> and other LAB, with the potential to support gut health and improve gut microbiota.	Enhances digestion and gut flora.	Gupta <i>et al.</i> , 2021

4.2 Probiotic potential

While less studied for their probiotic effects, certain legumes may support the growth of probiotics by providing a favourable environment in the gut. Proper processing methods such as fermentation can further enhance the prebiotic and potential probiotic properties of these legumes (Bhagyasri *et al.*, 2023).

5. Processing

To improve the nutritional content and lower antinutrient levels in underutilized legumes, a range of processing techniques have been investigated. Bhat *et al.* (2010) emphasized that, processing aids to remove antinutrients in wild and underutilized legumes that could serve as substitute sources of protein. Even though, the majority of underutilized oilseeds and legumes contain some toxic components

and anti-nutritional factors that may affect the body's ability to utilize protein and access minerals, these factors are known to be effectively eliminated or significantly reduced during the processing of the seeds, particularly during hydrothermal treatment, soaking, and fermentation (Das *et al.*, 2022). The processing conditions especially boiling reduced the saponin significantly whereas soaking and sprouting increased the saponin content in soybeans and jack beans (Shivani *et al.*, 2012). It includes milling, soaking, boiling, roasting, and fermentation (Falade 2020). The novel methods have been gaining attention due to the potential benefits they offer in terms of improving nutritional value, palatability, and overall utilization of these legumes (Quintieri *et al.*, 2023). It includes extrusion cooking, microwave heating, autoclaving, and irradiation (Rahate *et al.*, 2021).

Table 7: UELs processing methods and their products

S.No.	Legume	Processed product	Processing method	Reference
1.	Winged bean	Protein isolate	Extraction, precipitation, drying	Igene <i>et al.</i> , 2005
2.	Jack bean	Flour, animal feed	Milling, grinding	Kurniawati <i>et al.</i> , 2021
3.	Sword bean	Fermented bean paste	Fermentation, drying, grinding	Jung 2020
4.	Lima bean/ butter bean	Canned beans, frozen beans	Blanching, canning, freezing, drying	Ogechukwu <i>et al.</i> , 2017
5.	Hyacinth bean	Curry dishes, stewed beans	Soaking, cooking in stews or curries	Naiker <i>et al.</i> , 2020

6.	Broad bean	Canned beans, pureed beans	Blanching, canning, pureeing, roasting	Badjona <i>et al.</i> , 2023
7.	Velvet bean/ Lyon bean	L-dopa extract	Extraction with solvents, purification	Kavitha <i>et al.</i> , 2020
8.	Negro beans	Flour, tempeh (fermented)	Sprouting, milling, fermentation	Alfaro Diaz <i>et al.</i> , 2023
9.	Bambara groundnut	Flour, milk	Milling, soaking, grinding, sieving	Abdulsalami <i>et al.</i> , 2010
10.	Mung bean	Sprouted beans, noodles	Sprouting, frying, milling	Zhang <i>et al.</i> , 2013
11.	Yard long bean	Stir-fried dishes, pickled beans	Stir-frying, pickling	Li <i>et al.</i> , 2021
12.	Adzuki bean	Sweet paste, sprouted beans	Boiling, steaming, canning, sprouting	Huang <i>et al.</i> , 2023
13.	Rice bean	Porridge, sprouted beans	Boiling, sprouting, porridge making	Sharma <i>et al.</i> , 2023
14.	Moth bean	Sprouted beans, vadi (fermented)	Soaking, boiling, sprouting, roasting	Nasir <i>et al.</i> , 2022
15.	Stinky bean	Fermented beans (Sator)	Fermentation	Asikin <i>et al.</i> , 2018
16.	African yam bean	Protein-enriched food products	Cooking, milling, blending, extrusion	Ohuoba <i>et al.</i> , 2023
17.	Marama bean	Traditional snack food	Roasting, boiling, grinding	Alabi <i>et al.</i> , 2024
18.	Ground bean or Kersting's groundnut	Eaten raw, roasted, or processed into peanut butter and oil.	Roasting, milling	Adeoye <i>et al.</i> , 2021
19.	Yam bean	Canned jicama, flour, juice	Blending, canning	Buckman <i>et al.</i> , 2018
20.	Khejri/ tree of paradise	Bark powder, pods pickles, sangri (dried pods), prosopis gum	Seasoning, fermentation, extrusion	Singh <i>et al.</i> , 2023

6. Future perspective: Exploring the potential for nutritional security

As a predominantly vegetarian country, India has a promising opportunity to enhance nutritional security by diversifying dietary sources through the use of under-exploited legumes. These legumes, often overlooked in mainstream agriculture, are rich in protein, essential amino acids, dietary fiber, and micronutrients (Popoola *et al.*, 2022). Leveraging these underutilized crops can address malnutrition and promote food sovereignty. Recent studies emphasize their adaptability to various climatic conditions, making them resilient to climate change impacts (Bisht *et al.*, 2023). It is important to envisage the sustainable use and conservation of indigenous knowledge and also for future research in phytomedicine toward effective management of human ailments (Seetharamu *et al.*, 2023). Future thrusts should focus on strengthening research on agronomy, developing processing techniques, and raising awareness among farmers and consumers. By harnessing the potential of these under-exploited legumes, India can achieve improved nutritional outcomes and greater agricultural sustainability.

7. Conclusion

Underutilized legume crops are a huge, mostly unexplored resource that holds great promise for supporting environmental sustainability, economic growth, global food, and nutritional security. They can be used to improve resource efficiency, improve soil fertility through nitrogen fixation, and provide ecosystem services like pollinator habitat conservation and pest control when incorporated into sustainable cropping systems like intercropping and agroforestry. Additionally, the promotion of under-utilised legumes presents opportunities for product development, market diversification, and value addition. To sum up, neglected legume crops offer several

advantages beyond their nutritional content. These advantages include resilience to climate change, environmental sustainability, and economic prospects. By embracing these underutilized resources and incorporating them into our diets and agricultural systems, we can help achieve the Sustainable Development Goals of promoting sustainable agriculture, ensuring healthy lives for all, and eliminating hunger.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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