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Review

The Role of Neglected Grain Legumes in Food and Nutrition Security and Human Health

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Abstract: Increasing demand for nutritious, safe, and healthy food, including the need to preserve biodiversity and other resources, signifies a prodigious challenge for agriculture, which is already at risk from climate change. Diverse and healthy plant-based diets may significantly reduce food insecurity, malnutrition, diet-related diseases, and other health-related issues. More attention to agricultural systems diversity is mandatory to improve the economic, environmental, ecological, and social sustainability of food production in developing countries. In this context, neglected legume production could significantly provide nutritional and healthy benefits for people while adhering to sustainability principles. However, the contribution of neglected legumes to food and nutrition security is still limited due to socio-economic challenges faced by farmers that contribute to the underutilization of neglected legumes, leading to overreliance on a few legumes with poor resilience to climatic perturbations, thus posing a risk to sustainable food production. While major legumes offer higher economic returns and more developed value chains, they also contribute to environmental degradation and resource depletion. Neglected legumes, on the other hand, provide ecosystem services, promote biodiversity, and offer climate resilience but face economic challenges due to limited market demand and underdeveloped value chains. Consequently, food nutritional insecurity and human health concerns remain prevalent, especially in developing countries. There is an urgent need to promote neglected legumes in agricultural systems through policy change implementation, genetic improvement, and development, fostering international cooperation to share knowledge, technologies, and best practices in the production and utilization of neglected legumes. This review comprehensively explores the utility of neglected legumes for food, nutritional security, and human health. It identifies knowledge gaps that should be prioritized as part of research strategies for sustainable future food systems in sub-Saharan Africa.

Keywords: bioactive compounds; climate change; dietary diversity; malnutrition; protein security; sustainable food production

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1. Introduction

Approximately two billion people worldwide, primarily children, suffer from micronutrient deficiencies. This results in 151 million stunted children under the age of five and millions more with delayed cognitive development [1,2]. World hunger increased in 2020 during the COVID-19 pandemic [3]. Over one-third of the world's undernourished people reside in Africa (282 million) and Asia (418 million). In 2020, 2.37 billion people did not have access to adequate food, and this has increased by 320 million since 2019 [3].

Subsequently, malnutrition is projected to affect more than half of the world's population within the next few decades [4]. Due to the high levels of food insecurity, the sustainable development goals of achieving zero hunger, good health, and well-being will not be accomplished by 2030 [5]. These demand the use of neglected legumes to supplement diets with vital nutrients, including vitamins, minerals, carbohydrates, amino acids, and dietary fiber.

Neglected legumes are domesticated crops with useful traits but are less important than the main global crops because of limitations in supply and use [6]. Their key characteristics are their innate qualities, which enable them to greatly replenish the soil, increase food and protein security, and resist the effects of abiotic stress and climate change [7]. These neglected legumes include marama bean, horse gram, rice bean, grass pea, moth bean, tepary bean, Andean lupin, pigeon pea, Bambara groundnut, and cowpea. They currently lack a common international and well-established value chain. They are solely of regional significance in geographic, social, or economic aspects [8]. However, they play a critical role in the food system for both human and animal consumption. They have the potential to alleviate malnutrition and hidden hunger through nutritious, inexpensive, climate-resilient, and smart-agricultural food systems [9,10]. Neglected legumes are widely regarded as the most affordable plant-based sources of dietary protein, carotenoids, polyphenols, and high-energy sources that are low in glycemic index, fat, and cholesterol. Their seed content and structure provide a nutritionally beneficial matrix for the entire meal [11]. They also contain essential phytochemicals, antioxidants, and bioactive non-nutrients that play an increasingly important role in improving humans' health and helping reduce the risk of mortality due to their advantages against major chronic diseases and associated risk factors, such as cardiovascular disease, diabetes, cancer, obesity, and gastrointestinal health [11–13].

Integration of neglected legumes in production systems could play an essential role in replacing imported grain legumes in the future through providing multiple services in line with sustainability principles due to their capacity to improve soil fertility, symbiotic nitrogen fixation, and mitigation of greenhouse gas emissions [10,14]. Their extensive adaptation to poor soils and tolerance to biotic and abiotic environmental stresses compared to major legumes could potentially improve the livelihoods of smallholder farmers globally [15,16]. In the context of climate change, as diversification crops in agroecosystems, they can break the cycle of pests and diseases and contribute to balancing the deficit in plant protein production worldwide [16,17]. As a result, producing more protein from neglected legumes as an alternative to livestock protein for human consumption will lead to a reduced carbon footprint.

Despite their significance for the subsistence of African countries, neglected legumes remain poorly documented, with a feeble or lack of official seed supply systems [16]. This negligence has resulted in a lack of genetic improvement, which has resulted in lower yields in both quality and quantity. Moreover, dependence on neglected legumes raises intrinsic agronomic, ecological, nutritional, and economic concerns, and it is projected to be unsustainable over the long term, particularly considering the effects of climate change [18]. Hence, a global threat exists because of the discrepancy between the amount of food available and the nutritional requirements of the human population. Therefore, there is a pressing need to promote the production and utilization of neglected legumes to improve the economic, environmental, and social sustainability of food production in developing countries. As a result, this will significantly contribute to securing food security and meeting the nutritional demand of an ever-increasing world population. This review provides comprehensive potencies of neglected legumes for food, nutritional security, and human health and will aid in defining the priorities for future research.

2. Overview of Neglected Legumes

Neglected legumes are considered minor crops that originated in Sub-Saharan Africa (Table 1; Figure 1) and are already cultivated but underutilized globally, with a relatively low global production and market value. Some of these crop species may be widely distributed globally but are limited to local production and consumption. Hence, meeting food and nutrition requirements and alleviating hunger in rural households [19]. They are grown for fodder, oil, and sources of traditional medicine that play a significant role in the subsistence of local communities.

Neglected legumes are highly adapted to varying ecogeographical settings, withstanding conditions such as heat, drought, frost, and cold. They perform well in cropping systems with limited or no external inputs (Figure 2) but are inadequately documented with respect to their utility and cultivation requirements [6,8]. They are also essential in crop rotation strategies to fertilize agricultural soils. These attributes could be scientifically explored for crop improvement and sustainable utilization. However, neglected legumes have received minor attention from researchers, plant breeders, growers, policy and decision-makers, traders, technology providers, and consumers due to several factors, including agronomic, genetic, economic, and social factors [5,16,20].

The neglected legume species include tepary bean (*Phaseolus acutifolius*), marama bean (*Tylosema esculentum*), horse gram (*Macrotyloma uniforum*), grass pea (*Lathyrus sativus*), Bambara groundnut (*Vigna subterranea*), Andean lupin/Tarwi (*Lupinus mutabilis*), hyacinth bean (*Lablab purpureus*), adzuki bean (*Vigna angularis*), rice bean (*Vigna angularis*), moth bean (*Vigna aconitifolia*), pigeon pea (*Cajanus cajan*), and cowpea (*Vigna unguiculata*) [6,20], as presented in Table 1. Based on their utilization and industrial and economic values, the major legumes that are extensively researched, well documented, and widely cultivated with well-defined agronomic practices include soybean (*Glycine max*), common bean (*Phaseolus vulgaris*), groundnut (*Arachis hypogaea*), chickpea (*Cicer arietinum),* and pea (*Pisum sativum).* These major legumes show poor resilience to climatic perturbation despite being in mainstream cultivation and dominating international markets [21]. It is becoming clear that supplementing major legumes with neglected legumes is a viable strategy for sustainably addressing the issues of food and nutrition insecurity and human health. Their promotion as complementary alternative food sources in agriculture will potentially replace imported grain legumes in the future, thus improving the economic, environmental, ecological, and social sustainability of food production in developing countries. In addition, their adoption as potential alternatives for establishing resilience in smallholder farming systems will contribute to zero hunger, improved consumer health, and poverty alleviation. This is because neglected legumes are easy to grow since seeds can be locally sourced and they have low inorganic fertilizer, irrigation water, pesticides, and other input requirements.

Moreover, protein-calorie malnutrition is prevalent in many developing countries in the tropics and sub-tropics. Incorporating neglected legumes into the diet will act as a safety net to meet the challenges of malnutrition and address the issues of nutrient deficiency. Enhancement and improvement of protein supply to meet the growing population's demand necessitate utilizing unconventional protein sources for further use in Sub-Saharan Africa. Harnessing the untapped nutritional and genetic potential of neglected crops has been regarded as one of the prime strategies for improving food and nutritional security in Africa over the last decade [22]. Therefore, considerable research is still required to document the nutritional and nutraceutical advantages for both species and variety levels.

Figure 1. Images of neglected legumes (Pictures no. (**A**–**F**)); Source [22].

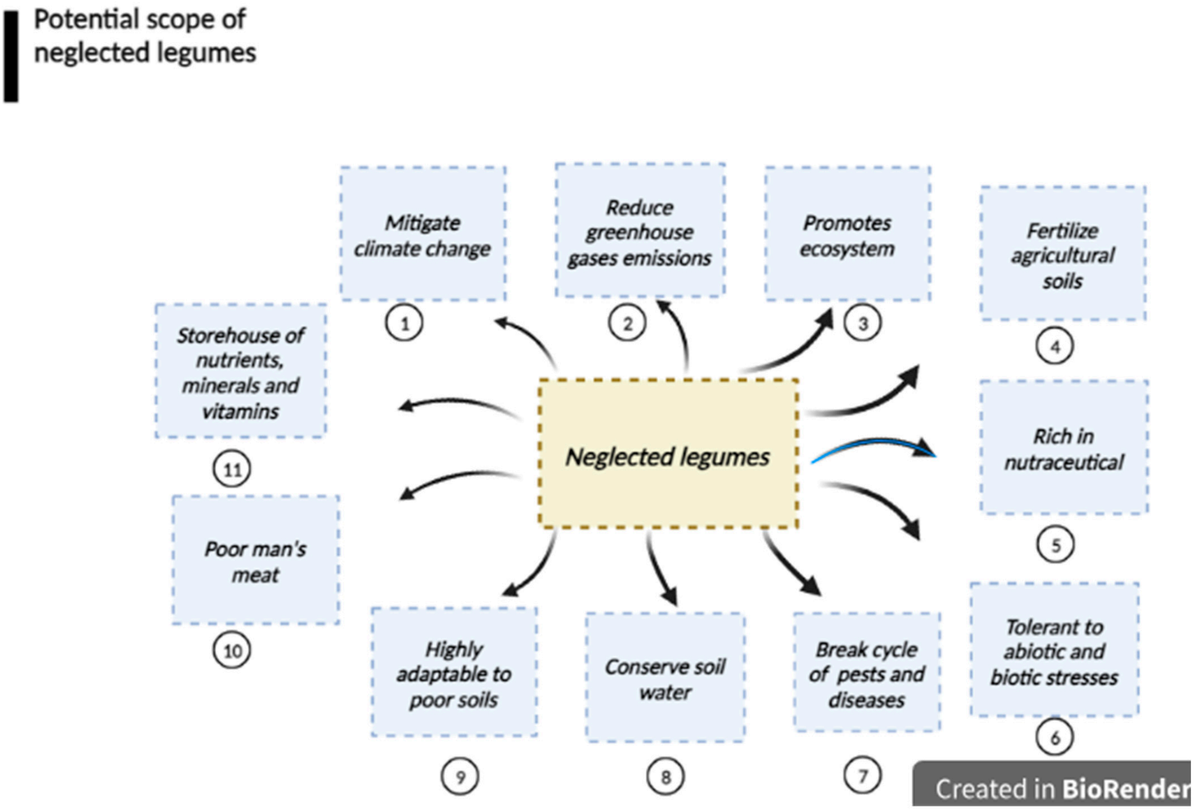

Figure 2. Potential scope of neglected legumes' inclusion into cropping systems.

Table 1. Origin and distribution of neglected legumes.

Legume	Origin and Distribution	References
Tepary bean (*Phaseolus acutifolius*)	Central Mexico to Southwestern United States	[23,24]
Marama bean (*Tylosema esculentum*)	Native to Kalahari Desert, Southern Africa arid areas (Namibia, Botswana, South Africa)	[25,26]
Horse gram (*Macrotyloma uniflorum*)	Native to Southern Asia (India) and tropical Africa	[27,28]
Bambara groundnut (*Vigna subterranean*)	Sub-Saharan African countries (from the Sahara to South Africa and Madagascar)	[29,30]
Andean lupin (*Lupinus mutabilis*)	South America, Columbia, north Argentina	[31,32]
Hyacinth bean (*Lablab purpureus*)	Originated from Africa, distributed to India	[33]
Adzuki bean (*Vigna angularis*)	East Asian countries (Korea, China, Japan)	[34,35]
Rice bean (*Vigna umbellate*)	Native of South and Southeast Asia, USA, Australia, East Africa, Java, Fiji, Bangladesh, and Nepal	[36]
Cowpea (*Vigna unguiculata*)	West Africa, Asia, Southern Europe, Southern America, Central and South America	[37,38]
Moth bean (*Vigna aconitifolia*)	India, Pakistan, southern China, and Southwestern America	[39]
Grass pea (*Lathyrus sativus*)	South Asia, Sub-Saharan Africa, Mediterranean region	[40]
Pigeon pea (*Cajanus cajan*)	Originated in India, spreading to East and West Africa, Southeast Asia, Latin America, and Caribbean	[41,42]

3. Production of Neglected Legume Crops

In terms of production and cultivated area, neglected legumes lag significantly behind cereal crops. In sub-Saharan Africa, only 27 million hectares are allocated for planting legume crops, with an estimated annual production of about 19 million metric tons [43]. These legumes are produced at less than 1 million metric tons per hectare, which is below the anticipated worldwide yield. The yield gap is because legumes are considered secondary crops to cereals regarding consumer preferences, and research activities have thus focused more on cereal production [44]. Limited attention by research and development programs, the use of unimproved varieties, a lack of quality seeds, and lack of knowledge about cultivation, use, and nutritional value also contribute to the gap in legume production systems [45,46]. Legumes cultivation depends not only on the effect of farmers' choices. However, they play a key role not only in such decisions but also in policymakers, who are responsible for providing practical strategies to support the inclusion of legumes in cropping systems.

The nutrition policies have not focused on creating awareness among people about the importance of dietary diversity and the addition of neglected legumes to their food basket [47]. Hence, the high demand for cereals has pushed legume production to marginal environments characterized by low rainfall and poor soils, a characteristic of most smallholder and communal farming systems. Production of legumes in developing countries, particularly in Africa, is practiced by smallholder farmers whose average household head age is 48 years; average schooling is less than 4 years; the average area of land under grain legumes is less than 0.2 ha; and arable landholdings are fragmented mainly due to the insecure land tenure systems [48]. Hence, neglected legumes are primarily produced by vulnerable and marginalized groups with limited skills and technology to produce and process them into nutritious food products [43]. They are grown primarily as secondary crops intercropped with cereals and occasionally used as rotational crops with cereals because of their significant role in biological nitrogen fixation. As a result, the yield and production of neglected legumes over the past decades have stagnated in most developing countries. For more economic gain, impoverished farmers have begun to produce important staple crops instead of neglected legumes. They have been mostly replaced by cash crops or crops such as soybeans, peanuts, and chickpeas.

3.1. Bambara Groundnut (*Vigna subterranean*)

The leading producers of Bambara groundnut include Nigeria, Burkina Faso, Ivory Coast, Ghana, Mali, Senegal, and Niger in West Africa; Tanzania, Malawi, Zambia, and Madagascar in Eastern Africa; and Chad and DR Congo in Central and South Africa (Figure 3).

An estimated 330,000 metric tons of Bambara groundnut are produced in Sub-Saharan Africa annually, 40% to 45% of which are produced in West Africa [29]. In comparison to groundnut (estimated at 37.1 million metric tons) and cowpea (estimated at 8,986,191.25 metric tons), the global production is modest [49]. Figure 3 provides an overview of certain countries' annual output figures. Yield can range from 900 kg/ha to 1200 kg/ha. The production of Bambara groundnut is considered low globally, and on-farm yields are unstable.

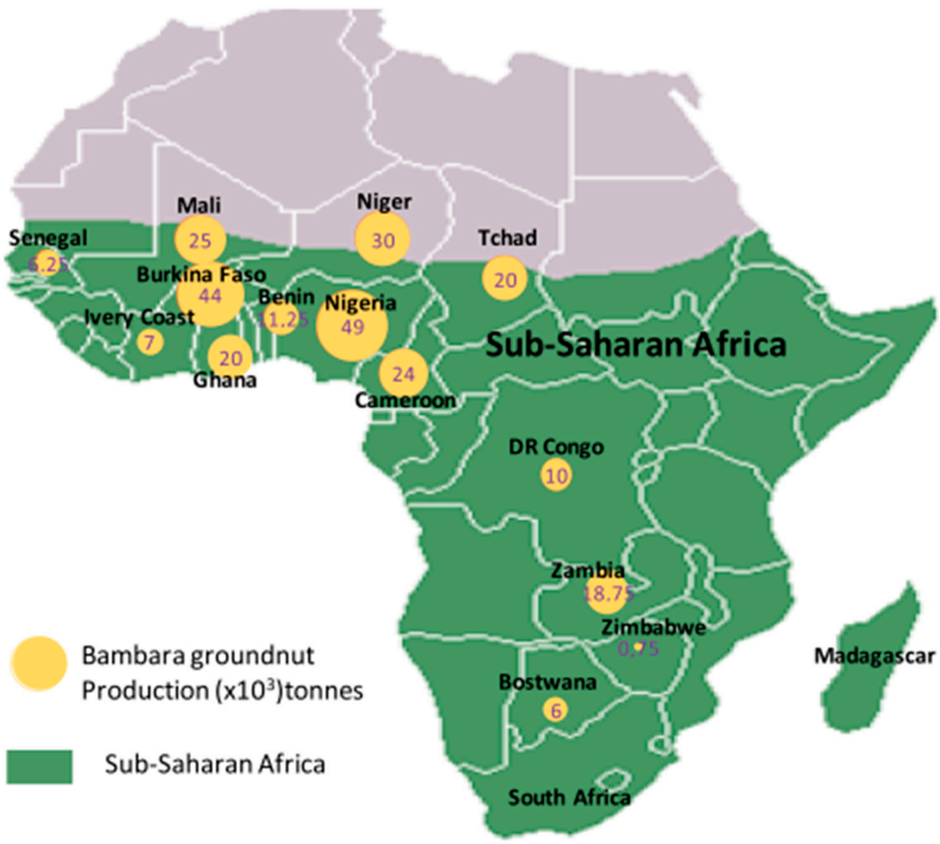

Figure 3. Bambara groundnut leading producers and annual production [29].

3.2. Cowpea (*Cajanus cajan*)

Cowpea is produced on roughly 12 million hectares worldwide annually, amounting to about 8,986,191.25 metric tons. Over the past three decades, cowpea production has increased globally at an average rate of 5%, with yearly production area growth of 3.5% and yield growth of 1.5%; area expansion accounted for 70% of the overall growth during this time. West Africa is where the majority of cowpea and Bambara groundnut production occurs. Over 80% of cowpea production in Africa is produced in West Africa, mainly in

Nigeria, Niger, Burkina Faso, Mali, and Senegal. This continent accounts for around 84% of the world's cowpea-producing area and 83.4% of the crop's total global production. Despite the significance of cowpea, Sub-Saharan African farmers only produce less than 650 kg/ha of the crop annually, compared to a potential output of around 2000 kg/ha [15].

3.3. Horse Gram, Andean Lupin, and Other Neglected Legumes' Production

Horse grams are produced globally at a rate of 1,725,395.71 tons and 1407.2 kg/ha, comparable to Andean lupin at 1,384,963.65 tons and a rate of 6218.9 kg/ha. Andean lupin production is mostly concentrated in South America's Andes region, particularly in Ecuador, Chile, Peru, and Bolivia. According to [50], Australia contributes 1.1 million metric tons to global production. However, sub-Saharan Africa produces a relatively small quantity of Andean lupins, with the majority coming from South Africa, Kenya, and Tanzania. Andean lupin is not yet regarded as a commercial crop due to several challenges to its adoption, which include a long cropping cycle, poor and unstable yield production, and prevailing issues regarding the crop's integration into local agriculture systems as a result of biotic and abiotic stresses [50].

China is the world's biggest producer of adzuki beans, producing 0.9 million metric tons with a productivity of 1100 kg/ha [51]. Rajasthan has 0.22 million metric tons of moth beans, almost 85% of the world's total production. The yield is estimated to be between 70 and 270 kg/ha, which is low. Experimental seeds can yield up to 2600 kg/ha in Australia and the United States [52]. This recommends the necessity of enhancing breeding efforts for these neglected legumes. Globally, 787.29 million metric tons of rice beans are produced each year. Asia produces the most, with 708.15 million metric tons annually, followed by Oceania (437,147.28 million metric tons), Africa (37.19 million metric tons), South and North America (602,211.52 million metric tons), and Europe (3.78 million metric tons).

3.4. Production of Marama Bean, Grass Pea and Pigeon Pea

3.4.1. Marama Bean (*Tylosema esculentum*)

Marama bean is a native crop of the Kalahari Desert of South Africa, with a yield potential of 2 tons per hectare. In Namibia and Botswana, it grows naturally. As a result, only a few farmers produce marama beans on small plots, with a total farmed land area of about 50 hectares. In Australia, Israel, Kenya, and the United States of America, the marama bean is undergoing experimental cultivation (Omotayo and Aremu, 2021) [53]. The crop is also barely grown in Zambia and Mozambique, while it is found in South Africa's provinces such as the Northwest, Northern Cape, Limpopo, and Gauteng. Marama bean production is limited by several factors, including the lengthy seed-to-seed cycle, which prompts farmers to prefer early maturing varieties. Therefore, resolving this problem becomes a fundamental breeding goal. The low seed output is another drawback, which is currently the focus of major selection breeding research (Chimwamurombe and Naomab, 2024) [26]. In addition to lobbying governments and donor organizations for inclusion in seed production and breeding programs, overcoming these obstacles would make it easier to promote marama bean cultivation as a conventional crop.

3.4.2. Grass Pea (*Lathyrus sativus*)

Approximately 1.20 million tons of grass peas are produced annually on an estimated 1.50 million hectares worldwide [54]. This annual cool-season legume crop is important both economically and ecologically in South Asia and sub-Saharan Africa, and to a lesser degree in North Africa, Central and West Asia, southern Europe, and South America. It is mostly cultivated for feed and fodder in other nations and for consumption in Bangladesh, Nepal, India, Pakistan, and Ethiopia. The crop is also produced to a lesser degree in the Middle East (Syria, Lebanon, Palestine, Iraq, Afghanistan), Northern Africa (Egypt, Morocco, Algeria), China, Chile, and Brazil, as well as many European nations (from southern Germany to Portugal and Spain and east to the Balkans and Russia [40]. The production of grass peas has risen in Bangladesh and Ethiopia but declined in the Mediterranean [55]. This increase in production could be the result of the grass pea's recent popularity as a crop to produce in problematic soils. According to Kumar et al. (2021) [54], due to the paucity of research on the genetic and genomic resources available for grass peas in global gene banks, the crop has not made significant strides.

3.4.3. Pigeon Pea (*Cajanus cajan*)

The crop is produced on 5.4 million hectares of land globally, yielding about 4.49 million tons per annum. Approximately eighty-two (82) countries throughout the world cultivate it. India produces over 72% of the world's pigeon peas. In Africa, Malawi, Tanzania, Kenya, Mozambique, and Uganda account for 4% of the world's pigeon pea production. Additionally, the crop is produced on 0.56 million hectares in Eastern and Southern Africa. According to Fatokimi and Tanimonure (2021) [56], the crop is usually produced with other crops such as cassava, sorghum, millet, and yam. Pigeon pea is mostly grown on about 190,000 hectares of land (3.52% of the world's output land) in Nigeria's northern and southern Guinea savannah agro-ecological zone.

4. Nutritional Value of Neglected Legumes

Today, red meat consumption is the primary protein source and has surpassed other protein sources such as legumes, fish, dairy products, poultry, and eggs [57]. This has detrimental effects on both human health and the environment because livestock farming is one of the major contributors to greenhouse gas emissions [58]. By 2050, the global consumption of processed food and animal-source foods must be reduced by more than 50%, and plant-based food consumption must grow by more than 100% to make the transition to healthy dietary patterns [59]. Neglected legumes' unique nutritional profile makes them a suitable key candidate for diverse dietary patterns, such as plant-based dietary approaches to human diets. They are considered the cheapest source of nutrients, with an undisputed nutritional key role in both human and animal [60] diets. Due to their abundant supply of macro- and micronutrients, they are consumed as dried pulses, sprouts, green leafy vegetables, and as livestock fodder in various parts of the world [61]. Their seeds, particularly Bambara groundnut and marama bean, are used to produce low-fat vegetable yogurt and vegetable milk, which is comparable to soy milk or dairy milk, and are utilized in numerous meal preparations to raise the protein level [62,63]. Marama bean seeds are also prepared in different ways, such as roasting, boiling, or grinding, and are used for producing butter and porridge [53].

In comparison to cereal grains, neglected legumes' seeds are valued as an inexpensive poor man's meat, rich in high-quality protein with essential amino acids, carbohydrates, starch, dietary fiber, pectin, sugar components, and oil rich in mono- and di-unsaturated fatty acids and containing no cholesterol [60]. For nutritional composition, the major legumes are comparable (Table 2). For example, neglected legumes, including Andean lupin seeds (45%), marama beans (38%), grass pea (34%), and cowpea (32%), have a higher protein content than common beans (25%), groundnut (30%), and chickpea (30.5%). Due to their high oil content, the marama bean and Andean lupin seeds are prospective substitutes for oilseed legumes like soybean and groundnut [22]. Marama beans (43% oil content) have roughly double the oil content of soybeans and groundnuts. Andean lupin has a similar oil content as soybean but is nutritionally superior since its oil is polyunsaturated and has a high linoleic acid concentration [64,65].

The hyacinth bean is rich in essential amino acids, especially lysine, which is typically low in most cereals [66]. Rice bean is also notably rich in lysine, methionine, tyrosine, valine, tryptophan, vitamins, and minerals (thiamine, niacin, and riboflavin) [67]. Tryptophan and lysine are two essential amino acids abundant in cowpea, which is low in fat but rich in minerals [68–70]. The Bambara groundnut has a considerably greater methionine concentration than several beans. Its protein contains essential amino acids in sufficient quantities to meet the guidelines set by food and agriculture organizations [70]. The nutritional value of rice bean, lupin, Adzuki bean, cowpea, tepary bean, and pigeon pea has been increasingly acknowledged due to their high content of carbohydrates and dietary fiber (Table 2). Their starch serves as a source of energy in the diet of humans and has a significant polysaccharide that has drawn the attention of nutritionists and food technologists.

Table 2. Proximate nutritional composition of neglected versus major legumes.

				Nutrient Composition (%)				
Neglected Legumes	**Energy (kcal)**	**Protein**	**Fat**	**Carbohydrates**	**Dietary Fiber**	**Ash**	**Price per\kg ($)**	**References**
Tepary bean	158	21.5–25.3	0.9–1.2	47.4–51.5	16.2	4.9–5.0	8.00	[71,72]
Marama bean	525	29.0–38.0	36–43.0	19.0–27.0	16	2.5–3.7	35.20	[53,73]
Horse gram	321	19.0–29.0	0.6–2.6	57.2	5.3	3.0–3.8	15.99	[27]
Bambara groundnut	381	17.4–25.2	6.0–7.9	51.0–70.0	10.0	3.0–5.0	12.55	[74,75]
Andean lupin	370	40.0–45.0	6.0–7.9	51.0–70.0	18.9	3.0–5.0	13.50	[76]
Hyacinth bean	338	23.7–24.9	1.2	54.2–67.2	5.8	3.2–3.5	0.78	[77]
Adzuki bean	294	15.0–29.0	0.4–2.1	40.0–60.0	16.8	2.0–7.0	11.99	[78]
Rice bean	346	18.6–26.0	0.3–2.0	60.7	21.5	3.0–4.3	12.99	[79]
Cowpea	336	20–32	0.6–1.3	50–60	18.2	2.9–3.5	05.40	[70,80]
Moth bean	343	21.9–28.0	1.5	61.5	4.5	3.4	56.00	[81]
Grass pea	348	18–34	1.0–1.6	52.4–59.6	8.3	1.5–2.1	0.73	[82,83]
Pigeon pea	361	19–21.7	1.2–1.3	62.7	15.5	3.9–4.3	17.09	[84]
Major legumes								
Soybean	374	33.0–45.0	19.9	30.2	10.3	3.1	0.52	[6,85]
Common bean	340	16.5–25.2	0.3–1.3	43.5–67.9	4.30	4.2–4.5	2.80	[86,87]
Groundnut	602	26–30	48.0	15.5–16.13	3.0	2.0–2.6	0.68	[88]
Chickpea	343	12.6–30.5	3.8–10.2	52.4–70.9	22.7	2.5–3.2	16.49	[89]
Pea	245	24.4–32.5	0.8–3.9	51.3	13.4	3.1–4.1	16.89	[90]

Neglected legumes also constitute a source of minerals, including iron, copper, zinc, sodium, calcium, magnesium, phosphorus, potassium, and manganese (Table 3). The iron content of grass pea, Andean lupin, tepary bean, horse gram, and rice bean is higher compared to major legumes including soybean, common bean, groundnut, chickpea, and pea [91,92]. Inclusion of these neglected legumes in the diet has been suggested as a safe alternative to iron supplementation due to their abundance in the iron-rich protein ferritin. Lupin seeds present the highest level of manganese compared to the content found in soybeans, chickpeas, and peas. Bambara groundnut seeds contain a higher zinc content than other neglected legumes and major legumes [93]. This legume is also rich in phosphorus and magnesium compared to other neglected species.

In comparison to other legumes like groundnut and pea, the rice bean is particularly rich in calcium and potassium, while horse gram seeds have higher levels of copper than common bean, chickpea, and soybean [94].

Table 3. Mineral composition of neglected versus major legumes.

	Minerals (mg/100 g) Dry Matter									
Neglected Legumes	**Fe**	**Cu**	**Zn**	**Na**	**Ca**	**Mg**	**P**	**K**	**Mn**	**References**
Tepary bean	12.6	3.7	6.1	34.2	210	281	432	1607	3.6	[95]
Marama bean	4.0	1.0	6.2	64.5	241	274	503	954	1.9	[96]
Horse gram	11.9	5.5	3.4	37.3	105	172	310	415	1.5	[91]
Bambara groundnut	6.7	3.0	19.7	25.2	76	555	563	2200	0.8	[93,97,98]
Andean lupin	16.9	1.3	5.2	20	98	308	249	237	3.8	[99]
Hyacinth bean	3.5	1.3	9.1	43	88	283	395	404	1.6	[100]
Adzuki bean	4.6	0.7	4.1	18.4	65	120	386	1223	1.3	[78]
Rice bean	10.9	4.2	3.1	22.2	274	156	126	2618	2.7	[92]
Cowpea	8.2	0.3	3.9	16	110	184	424	1112	0.2	[101–103]
Moth bean	9.6	1.1	4.4	11.5	120	225	320	2257	1.8	[104]
Grass pea	18.4	0.7	4.4	44.1	200	116	512	644	1.8	[105]
Pigeon pea	4.7	1.8	8.2	12.0	167	127	293	1941	2.4	[106]
Major legumes										
Soybean	8.5	2.4	2.2	27.9	226	236	546	1730	1.2	[107]
Common bean	9.8	1.1	2.3	41.9	183	197	850	2159	2.0	[108]
Groundnut	6.9	2.7	3.4	42	89	210	340	988	2.9	[103]
Chickpea	6.2	2.3	6.2	29.5	114	168	387	1279	1.3	[94]
Pea	5.8	2.4	5.7	93.8	157	110	374	937	1.5	[109]

Neglected legumes, however, form only a minor part of most current human diets, despite the deficiencies of these micronutrients among rural populations in developing countries that lack the financial means to acquire and consume sufficient quantities of red meat, chicken, fish, fruit, and vegetables [11]. More than 12 million adult deaths have been attributed to poor diets, a 15% increase since 2020. North America and Europe each have the highest percentage of early mortality associated with dietary concerns (31%), whereas Africa has the lowest rate (17%) but is still considerable [110]. Only 1.1% of the world's overall food supply and 1.3% of the world's total vegetable food supply come from legumes, which is relatively low. Hence, there is a need to supplement poor diets by including neglected legumes.

The global nutrition report indicates that the global nutrition targets will not be achieved by 2025 [111]. For the past two years, there has been a substantial increase in the number of undernourished people, and by 2021, up to 828 million people were hungry worldwide. The frequency of undernourishment grew from 8% in 2019 to roughly 9.3% in 2020 to 9.8% in 2021. The number of hungry people in Africa continues to rise [112]. As of 2020, over one-third of the continent's population was undernourished. In Africa, 282 million people experience hunger, which is more than double of any other region globally. Conditions are deteriorating across East Africa, where 7.2 million people are at risk of starvation, and another 33.8 million face acute food insecurity. Around 12.8 million children are acutely malnourished. In this regard, there is a need to direct attention to the nutritional profiling of various neglected legumes to increase their value chain, utilization, and production of cheap and innovative value-added products to alleviate food and nutritional insecurity.

5. Utilization of Neglected Legumes

Even though neglected legumes could produce better food products, more naturally balanced diets, better pharmaceutical products, natural pesticides and flavorings, dyes, and beverages, numerous food legumes are still underutilized [113]. However, the seeds are rich in vitamin A, leucine, and lysine. They can be eaten fresh, fried, boiled, tinned, frozen, baked, dried, or roasted; they are typically cooked before eating [114,115]. Dishes include salads, casseroles, soups, and stews. Vegetables are made from both immature and mature pods. Mature seed flour is used in other recipes and combined with oil or butter to make porridge. Bambara groundnut is also canned. Additionally, the haul can be used for animal feed. According to [113], the processing and marketing status have been recorded. Horse gram seeds are fermented to produce a sauce similar to soy sauce. Mature dry seeds of neglected legumes can be used as a pulse or combined with other components to prepare meals; their flour can be used as bean paste or combined with bread flour to produce noodles. Immature pods from the Bambara groundnut are used in soup, and the immature seeds are typically consumed raw, cooked, or grilled. Like many other underutilized dietary legumes, rice beans are a multipurpose species. Asia uses immature pods and leaves as a vegetable and a pulse. Soups and stews are also cooked with the seed. Neglected legumes could also be consumed with cereals, tubers, roots, and other crops [116,117]. They can be used with grains, like sorghum, to make bread [118]; they can also be combined with maize to make blend extrudate, which can then be turned into flour [119]. Ref. [120] suggests using lime beans as a thickening agent in soups to make biscuits.

6. Health Benefits of Consuming Neglected Legumes

Good health is undoubtedly a universal concern and the desire of every human being. Including neglected legumes in the daily diet has many beneficial physiological effects in controlling and preventing various metabolic diseases such as diabetes mellitus, coronary heart disease, and colon cancer [85]. The role of legumes as therapeutic agents in the diets of people suffering from metabolic disorders is currently gaining interest. They produce a wide range of secondary metabolites, which serve as their chemical armory for defense against predators [121]. The variability in these secondary metabolites allows the classification of genera and subgenera based on chemical taxonomy. Those metabolites include anti-nutrients such as inhibitors of digestion and compounds interfering with human metabolism, reaching as far as brain function and hormonal control. Some of these metabolites are beneficial because they inhibit cancer cells or their antioxidant activity, which can delay aging in humans [121,122].

The low glycaemic index and high content of undigestible fibers in neglected legumes (e.g., Bambra groundnut, pinto, navy, kidney, lima, and black beans) aid with glycaemic control in diabetic individuals, contributing to preventing insulin resistance, which represents the prodrome of type II diabetes [123]. High-soluble dietary fiber lowers cholesterol levels by raising the ratio of bile acid to salt excretion in the feces and supplying colonic bacteria with a substrate converted to short-chain fatty acids anaerobically in the intestine (acetate, propionate, and butyrate) [124]. Butyrate inhibits histone deacetylase, which leads to gene expression changes in cancer cell proliferation, differentiation, and apoptosis [60,125].

Consuming legumes is also associated with a reduced breast and prostate cancer risk [126]. For example, lectin toxins and other compounds from the tepary bean have been found to be helpful in cancer chemotherapy [127]. Owing to two distinct types of bioactive proteins, each with a unique impact on cancer cells, this neglected legume is ten times more effective than chemotherapy in treating cancer [127]. The amino acid l-homoarginine present in grass pea provides benefits in overcoming the consequences of hypoxia, the inadequate oxygen supply at the tissue level associated with cancer tumor development [83]. Other effective cancer-fighting agents in neglected legumes include bioactive phytochemicals (saponins, phytic acid, and polyphenols) and micronutrients like folate and selenium. Folate also lowers the chance of neural tube abnormalities like spina bifida in [128] newborns.

Micronutrients present in neglected legumes play a vital role in bone health and teeth (calcium), protein synthesis, antioxidative activity, plasma membrane stabilization (zinc), enzyme activity and iron metabolism (copper), hemoglobin production, and prevention of anemia (iron), carbohydrate and lipid metabolism (zinc, chromium), Potassium and magnesium control blood pressure and are excellent at slowing down natural aging processes [129]. Neglected legumes such as adzuki bean, horse gram, moth bean, and hyacinth bean are used to treat various ailments such as dropsy, cough, bronchitis, cardiopathy, liver problems, and inflammation in traditional medicines from many parts of the world [130]. Moth bean also treats fever and irregular menstruation cycles in women [131], supports gut health, boosts the immune system [132], repairs muscles, promotes good bowel movement, and is suitable for renal diseases due to its properties as an astringent, diuretic, and tonic. Its roots are narcotic in nature [131]. Neglected legumes further contribute to a longer lifespan and improved mental wellness. Their consumption on a regular basis enhances satiety, reduces stress, anxiety, and sadness in older people, and encourages weight loss by reducing adipose tissue accumulation [133]. However, despite these health benefits, their actual intake remains low.

Isoflavones found in neglected legumes such as cowpea, adzuki beans, and mung beans prevent bone loss in postmenopausal women [134]. This includes anthocyanins, which trigger adipocytes to release adiponectin, a cardioprotective hormone with anti-inflammatory properties in blood vessel cells linked to a lower risk of heart attack in men and women [135]. Flavonoids are the most common bioactive compounds of neglected legumes, especially those with colored seed coats, and are the main class of polyphenols showing the highest antioxidant potential. This group encompasses proanthocyanins and anthoxanthins; they also exhibit free radical scavenging capacity, are anti-inflammatory, and positively impact the immune response [136].

Under stress conditions, neglected legumes produce several bioactive compounds for survival [137]. The bioactive compounds, along with carbohydrates (slow-release and indigestible), lipids (polyunsaturated fatty acids), and dietary fiber (soluble and insoluble), exert beneficial therapeutic effects on human health. Researchers have isolated and identified several bioactive compounds with potential nutraceutical properties (Table 4). Due to the bioactive compounds present, neglected legumes possess nutraceutical values and have vast potential to serve as raw materials for pharmaceutical companies. Isolation and extraction of bioactive compounds from edible and non-edible plant parts, including the seed coat, can be implied to manufacture potent natural antioxidants in the nutraceutical industry. However, several health benefits of underutilized legumes are yet to be ascertained and validated through the characterization of plant extracts, their identification, and the isolation of the related bioactive compounds.

Table 4. Health benefits of bioactive compounds found in neglected legumes.

Neglected Legumes	Bioactive Compounds	Health Benefits	References
	Phenolic acids		
Marama bean, rice bean, Bambara groundnut	Caffeic acid	Antioxidant, Antidiabetic, Neuroprotective, Anti-carcinogenic, Anti-inflammatory	[138,139]

Table 4. *Cont.*

Neglected Legumes	Bioactive Compounds	Health Benefits	References
Andean lupin, moth bean, pigeon pea, cowpea	Gallic acid	Anti-inflammatory, Antineoplastic, Antioxidant	[140–143]
Adzuki bean, mung bean	Vanillic acid	Cardioprotective, Antiapoptotic, Antioxidant, Neuroprotective, Hepatoprotective	[144,145]
Marama bean	Protocatechuic acid	Antidiabetic, Anti-carcinogenic, Antioxidant, Neuroprotective, Anti-atherosclerosis	[146]
Adzuki bean	Syringic acid	Neuroprotective, Antioxidant, Anti-inflammatory, Anti-microbial, Hepatoprotective	[147]
Grass pea, horse gram	p-Hydroxy Benzoic acid	Antiviral, Nematocidal, Anti-inflammatory, Antimutagenic, Hypoglycaemic, Antioxidant	[148,149]
Cowpea, Adzuki bean	p-Coumaric acid	Anti-microbial	[22]
Bambara groundnut, rice bean	Ferulic acid	Antidiabetic, Anti-carcinogenic, Neuroprotective, Antioxidant	[150]
Rice bean, black bean	Sinapic acid	Anti-bacterial, Antioxidant, Anti-carcinogenic, Neuroprotective, Anti-glycaemic	[22]
	Flavonoids		
Bambara groundnut, moth bean	Rutin	Antiarthritic, Analgesic, Antidiabetic, Cytoprotective, Neuroprotective, Anti-carcinogenic	[151,152]
Andean lupin	Myricetin	Antidiabetic, Analgesic, Anti-carcinogenic, Anti-microbial, Anti-hypertensive, Anti-mutagenic	[22]
Andean lupin, cowpea, Adzuki bean	Catechin	Anti-obesity, Anti-carcinogenic, Antidiabetic, Antioxidant, Neuroprotective, Hepatoprotective	[153]
Moth bean, pigeon pea	Hesperidin	Antioxidant, Anti-inflammatory	[22,154]
Bambara groundnut	Kaempferol	Anti-inflammatory, Anti-carcinogenic, Antioxidant	[22,155]
Bambara groundnut	Quercetin	Antiviral, Anti-carcinogenic, Anti-inflammatory	[22,156]
Marama bean	Phytosterols	Lower blood cholesterol levels	[157]
Bambara groundnut, pigeon pea	Saponins	Lower blood cholesterol and glucose level, Anti-carcinogenic, Immune-stimulatory activity	[158–160]
Adzuki bean, cowpea, mung bean	Carotenoids	Eye protective, Anti-carcinogenic, Antioxidant	[22,149,161]

7. Nutraceutical Properties of Neglected Legumes and Their Impact on Human Health

Neglected legume seeds are considered influential nutraceuticals because they have positive impacts on human health and can help prevent or treat diseases including diabetes, cancer, digestive tract disorders, cardiovascular disease, and overweight [162]. They contain phytochemicals that are essential to human metabolism in individuals who frequently consume neglected legumes [162]. Consuming phytochemicals through diet may have health benefits by warding off a host of illnesses and disorders, including inflammation and high blood pressure, while saponins play a key role as anti-cancer agents by limiting the development of carcinogenic substances in the colon. Additionally, they may have immune-stimulating effects by promoting the production of cytokines like interleukins and interferons. Saponins may also have several additional advantageous effects, including immunomodulatory, hypercholesterolemia, hypoglycemia, anti-inflammatory, anti-fungal, and anti-parasitic. The antioxidant content present in neglected legumes is important in the treatment of numerous illnesses, such as schizophrenia, autoimmune disorders, different respiratory diseases, and ocular disorders [163]. For instance, adding burned pigeon pea seeds to coffee can aid with vertigo and migraines, and fresh seeds can help with male urinary incontinence. On the other hand, kidney diseases are treated using immature seeds. The husks from pigeon pea seeds have strong antioxidant and anti-hyperglycemic properties, making them a possible organic source for nutraceuticals designed to treat hyperglycemia [164].

Neglected legume seeds also contain phytic acid, an antinutrient. It is kept in the endosperm of legume seeds as phosphate. Phytic acid functions as an anti-HIV agent by preventing the viral genome from being transcribed. Kidney stones are prevented from forming by phytic acid by reducing the solubilities of calcium, fluoride, and phosphate and shielding them from demineralization. It also aids in the prevention of cavities, plaque, and tartar in the teeth by chelating iron, suppressing iron-related initiation, and promoting carcinogenesis. Phytic acid also lowers the risk of colon cancer. Furthermore, because of its ability to boost natural killer cell activity, which is linked to reduced tumor incidence, it may have potential therapeutic utility in cancer [165]. Canavalia cathartica's lectin, Concanavalin C is used as a tissue marker, immunomodulator, and blood grouping agent [165,166]. Tumor cells are destroyed in the liver as a result of the immune cell responses that Concanavalin A triggers. Concanavalin A exhibits both autophagic and anti-hepatomic (immunomodulatory) activities after attaching to the mannose moiety. According to [167], phytosterols are important regulators of metabolism and cholesterol transport in the expression of liver genes, and they have an impact on intestinal genes through transcription factors.

8. Potential Anti-Nutritional Factors Present in Neglected Legumes

Neglected legume seeds have potential nutritional and health-promoting benefits. However, they also contain anti-nutritional elements, which may be harmful when eaten raw but, when processed and treated, may be beneficial to human health [162]. Their biological value and suitability as food are restricted by the existence of antinutritional substances. Researchers suggest that neglected legumes can trigger allergic reactions when consumed due to primary sensitization or cross-reactions with other legumes, which is also a serious problem [162]. For example, underutilized legumes such as Andean lupin have several antinutritional properties that can be either proteinous or non-proteinous [168]. Neglected legume seeds include a variety of ubiquitarian and specialized anti-nutritional components, including lectins, phytates, proteinase inhibitors, and polyphenols [169]. Antinutrients in neglected legume seeds are reported to restrict the amount of protein and carbohydrates that may be used. According to [170], the anti-nutritional components are rendered inactive by high processing temperatures; therefore, these adverse effects are only noticeable after consuming raw and unprocessed seeds or flour.

Most of the anti-nutritional factors associated with neglected legumes affect the digestive system. These factors include blocking digestive enzymes (like protease inhibitors), lectins that impair hydrolytic functions and transport at the enterocyte site, phytates and polyphenols that form insoluble complexes, and α-galactosides that increase gas production in the colon [168]. Trypsin inhibitors of the Kunitz and Bowman-Birk types as well as α-amylase inhibitors, such as those found in Adzuki beans, are the most well-known and frequently occurring protein inhibitors of legume seeds [171]. Additionally, phenolic chemicals, saponins, alkaloids, phytates, and other non-protein anti-nutritional substances found in neglected legume seeds hinder the biological uptake of these nutrients [162]. To increase the utilization of neglected legumes, several methods and mechanisms of action are used to lessen the influence of antinutrient factors (Table 5). Genetic manipulation (selection from natural or artificial diversity, genetic engineering of biosynthetic pathways, or of the toxic protein itself), post-harvest processing (germination, boiling, leaching, fermentation, extraction, etc.), or the selection of plant genotypes with low levels of these factors can all help achieve this reduction. Other methods include improving tolerance to antinutrient factors and supplementing diets with protective factors such as methionine, threonine, and feed enzymes.

Table 5. Antinutrients present in neglected legumes, processing methods, and mechanisms of action.

Neglected Legumes	Antinutrient	Processing Method	Mechanism of Action	References
Marama bean	Phytic acid, Polyphenols, Trypsin inhibitors, Lectins	Soaking, Germination, Fermentation, Boiling, Steaming, Heat treatment	Breaks down phytic acid, increasing bioavailability of minerals such as zinc, iron, and calcium, Breaks down polyphenols, reducing their binding to proteins and minerals Inactivates trypsin inhibitors, increasing protein digestibility	(Bower et al., 1998) [172]
Bambara groundnut	Phytic acid, Polyphenols	Soaking, Germination, Fermentation	Breaks down phytic acid and polyphenols, increasing bioavailability of minerals	(Musah et al., 2021) [98]
Rice bean	α-Galactosides, Oxalates, Saponins	Soaking, Germination, Fermentation, Boiling, Steaming	Breaks down α-galactosides, reducing gas production and improving digestibility Breaks down oxalates, reducing their binding to minerals such as calcium and magnesium Breaks down saponins, reducing their binding to cholesterol and increasing nutrient absorption	(Sharma et al., 2023) [173]
Grasspea	ODAP (β-N-Oxalyl-L-α,β-diaminopropionic acid)	Soaking, Boiling, Autoclaving	Breaks down ODAP, reducing neurotoxicity	(Hillocks and Maruthi, 2012) [174]
Pigeon pea, cowpea, Mung bean	Phytic acid, Polyphenols	Soaking, Boiling, Fermentation	Breaks down phytic acid and polyphenols, increasing bioavailability of minerals	(Gomezulu and Mongi, 2022; Gonçalves et al., 2016) [175,176]
Jack bean, Lima bean, African yam bean	Phytic acid, Polyphenols, Lectins	Soaking, Boiling, Fermentation	Breaks down phytic acid, polyphenols, and lectins, increasing bioavailability of minerals	(Akande, 2016; Farinde et al., 2018; Adegboyega et al., 2020) [177–179]
Andean lupin	Alkaloids, Phytic acid, Polyphenols	Soaking, Boiling, Autoclaving	Breaks down alkaloids, reducing toxicity, Breaks down phytic acid, increasing bioavailability of minerals	(Romero-Espinoza et al., 2020 [180]

Table 5. *Cont.*

Neglected Legumes	Antinutrient	Processing Method	Mechanism of Action	References
Adzuki bean	Raffinose, Phytic acid, Trypsin inhibitors, Polyphenols	Soaking, Germination, Fermentation, Heat treatment	Breaks down raffinose, reducing gas production and improving digestibility, Breaks down phytic acid, increasing bioavailability of minerals	(Sharma et al., 2019) [181]
Horse gram	Flavonoids, Trypsin inhibitors, Polyphenols, Phytic acid	Boiling, Steaming, Fermentation, Soaking, Germination, Fermentation	Breaks down flavonoids, reducing their binding to proteins and minerals Inactivates trypsin inhibitors, increasing protein digestibility	(Rizvi et al., 2022) [182]
Moth bean	Protease inhibitors, Amylase inhibitors, Saponins, Oxalates, α-Galactosides	Heat treatment, Autoclaving	Inactivates protease inhibitors, increasing protein digestibility Inactivates amylase inhibitors, increasing carbohydrate digestibility	(Bhadkaria et. al, 2022) [131]

9. Role of Neglected Legumes in Food Security and Sustainable Agriculture

It is projected that by 2025, there will be 8.1 billion people on the planet. This number will rise to 9.6 billion by 2050 and 10.9 billion by 2100 [183]. The imbalance in food production brought on by climate change could lead to a future food insecurity crisis because of the growing global population [184]. Malnutrition, a physiological condition caused by undernourishment or poor absorption or use of ingested nutrients due to some pathological conditions, must be prevented through the adoption of alternative and sustainable sources of food. African countries depend on staple cereal foods to sustain their diets, consuming only one type of carbohydrate, such as rice or maize, while lacking a significant source of protein [185]. As a result, protein energy deficiency is a threatening issue in developing countries [101]. Sustainable protein sources are needed to meet the enormous rise in protein demand that the world's population growth will bring about. Reintroducing neglected legumes to the diet as a promising intervention to address the world's food and nutrition concerns will significantly improve human nutrition and food security and reduce the risk of over-reliance on minimally significant crops. Consumers highly accept neglected legumes' proteins. They are abundant, sustainable, and not allergenic. Moreover, they can be utilized as functional additives to improve the nutritional value of processed meals and contribute to nutrient-dense, economically viable, and sustainable diets [186].

The sustainability of agricultural production systems has become crucial to increasing food security in the coming years. This is due to critical challenges, including arable land degradation, nutrient deficiencies, and climate change uncertainties. Neglected legumes are essential to this concern since they provide a wide range of services while adhering to sustainability standards [187]. Their intensification into cropping systems could provide various benefits to the ecosystem through reducing excessive use of external inputs (i.e., fertilizers and agrochemicals), improving soil structure, increasing soil organic carbon concentrations, enhancing soil health, quality, and fertility while also increasing production, and empowering local communities.

Soil fertility has emerged as one of the most significant biophysical constraints to increasing agricultural production, posing a threat to food security [188]. Smallholder farmers in marginal environments need more financial capacity to buy enough mineral fertilizers to restore the soil nutrients lost through harvested crop products. However, neglected legumes have the potential to effectively move fixed nitrogen to coexisting crops while lowering fertilizer costs [189]. It is fundamental to promote crop diversification of neglected legumes with high yield potential and nutritional value. Growing a diversity of neglected legumes is essential for improving nationwide nutrition, striving towards 100% food security, and increasing farmers' economic returns. When used as rotation crops, they help resource-poor smallholder farmers improve their financial status [190]. Their intensification in intercropping systems could improve yields, ensure production stability, increase scale efficiency, and provide insurance because farmers can still rely on the other crop if one fails. Neglected legumes are less susceptible to weeds, diseases, and pests than cereal crops. For instance, rice bean, tepary bean, adzuki bean, and horse gram have been observed to be immune to several pests and diseases. They break the life cycle of problematic pests, lowering the number and severity of pests in succeeding crops [191]. Therefore, farmers may reduce their reliance on pesticides and herbicides in subsequent crops because of the break-crop effect. Furthermore, introducing these legumes into agricultural rotation programs will help reduce greenhouse gas emissions and address the associated economic and environmental challenges.

10. Economic and Environmental Trade-Offs Between Neglected Legumes and Major Legumes

The economic and environmental trade-offs between neglected legumes and major legumes are complex and multifaceted. While major legumes offer higher economic returns and more developed value chains, they also contribute to environmental degradation and resource depletion. Neglected legumes, on the other hand, provide ecosystem services, promote biodiversity, and offer climate resilience but face economic challenges due to limited market demand and underdeveloped value chains. To promote sustainable agriculture and food systems, it is essential to promote the production and consumption of both neglected and major legumes. This can be achieved through developing markets for neglected legumes to increase their economic viability; investing in the development of neglected legume value chains to improve efficiency and reduce transaction costs; promoting sustainable agriculture practices, such as agroecology and regenerative agriculture, to reduce the environmental impacts of major legume cultivation; and conducting research and development to improve the productivity, disease resistance, and climate resilience of both neglected and major legumes. Adopting a holistic approach that considers both economic and environmental factors could promote the sustainable consumption of neglected legumes, ensuring food security, environmental sustainability, and equitable economic development.

11. Adaptation of Neglected Legumes to Climate Change

Global food security is currently threatened by climate change [192]. It is projected to negatively impact crop yield, leading to a decline of 25% by 2050 [193]. Inconsistent or poor yields have extensive consequences, as they mean less food for the household and less revenue for other essentials. Yield stability is crucial in ensuring food security, and for a household to be considered food secure, it must have regular access to adequate food with high nutritive value [194]. The struggle to attain food security is due to farmers' reliance on rainfall, accompanied by drought, low humidity, high temperatures, and increased agricultural risks, which are significant concerns that continue to threaten households' food security status [195]. Inclusion of neglected legumes, particularly in developing nations, could be crucial in tackling food and nutritional insecurity in the context of climate change due to their drought-tolerance characteristics, increased resilience against climate change, ability to increase crop yield under adverse conditions where other crops would fail, and the potential to support agricultural productivity on poor soils [196].

Hyacinth bean, tepary bean, cowpea, and adzuki bean are well-adapted to poor soils, salinity, acidity-alkalinity, and heavy metal stress [22]. Their tolerance implements a series of morphological, physiological, and biochemical changes for better adaptations. The adaptive mechanisms that enable them to survive and produce under extreme soil and agro-climatic conditions could be useful for low and erratic rainfall regions [22]. Their deep root system development and distribution allow for more efficient extraction of available water from deep levels of the soil profile [197]. Such adaptations result in more efficient water uptake; as a result, neglected legumes have the intrinsic ability to improve water use efficiency and save natural resources. Their inclusion will allow vulnerable resource-poor farmers to adapt to changing climatic conditions, improve resource use efficiency on a long-term basis, ensure yield stability, and alleviate food and nutrition insecurity, particularly in marginal environments.

12. Challenges to Mainstream Utilization of Neglected Legumes

Neglected legumes have received minor attention from researchers, plant breeders, growers, policymakers, traders, technology providers, and consumers due to agronomic, genetic, economic, and social factors [198]. As a result, they do not currently play a significant role in mitigating food and nutrition insecurity due to a lack of focused research and the utilization of unimproved cultivars, which has resulted in a lack of quality seeds and consequently low yield [22]. Over the past decades, these legumes have been primarily produced by vulnerable and marginalized groups with limited skills and technology to produce and process them into nutritious food products [34]. They are grown as secondary crops, intercropped with cereals, and occasionally used as rotational crops with cereals, which has resulted in stagnant production over the years in most developing countries. Lack of knowledge about the cultivation of neglected legumes and their use and nutritional value are other reasons for the gap in legume production [36,37]. In addition, nutrition policies have not focused on creating awareness among people about the importance of dietary diversity and the inclusion of neglected legumes in their food basket. Hence, the high demand for cereals has pushed legume production to marginal environments characterized by low rainfall and poor soils, a characteristic of most smallholder and communal farming systems.

There are several socio-economic challenges faced by smallholder farmers that contribute to the underutilization of neglected legumes. Smallholder farmers are highly vulnerable to climate change and environmental degradation, which lead to crop failures, reduced yields, and decreased incomes; have limited access to markets and market knowledge, making it challenging to sell their produce at competitive prices; have limited access to credit and financial services, which limits the investment in farms or management of risks; and have limited access to technology and extension services, which makes it challenging to adopt new technologies and crops and improve farming practices. Moreover, smallholder farmers, particularly women and marginalized groups, face social inequality and land rights issues, which limit access to land, credit, and other resources. Aging is another factor limiting the production of neglected legumes as a result of the limited involvement of youth in agriculture, which leads to a lack of innovation and modernization in farming practices. Promoting climate-resilient agricultural practices to enhance the sustainability of neglected legume production could be achieved by providing extension services and technology transfer to smallholder farmers, establishing market linkages, and providing market information; supporting women's and marginalized groups' participation in agriculture; and promoting social inclusion and empowerment through training and capacity building.

13. Potential Strategies to Resolve Underutilization of Neglected Legumes

A tremendous research effort and the development of value chains for neglected legumes could provide some impetus to challenge the dominance of major legumes [196]. Participatory action research could be used as an entry point to empower communities in developing countries, particularly vulnerable resource-poor farmers, by providing opportunities to co-learn and experiment with these neglected legumes [199]. The awareness and traditional knowledge of these legumes about their utility and cultivation need to be upgraded from a trivial farmers' level into a wide spectrum of scientific practices. This will lead to the adoption and utilization of these climate-smart neglected legumes and enhance the implementation of appropriate management approaches to promote sustainable food production. Secondly, advancements in speed breeding, genetic improvement for developing desirable traits, enhanced yield, and selecting elite attributes are essential across different climate-resilient cropping systems [200]. Therefore, intensive future research must focus on bringing the traits of these legumes into greater production integration, which could elevate their economic status in the global market. This will significantly increase intake and consequently contribute to the mitigation of current health and environmental-related global crises, including food and nutrition insecurity.

Food and nutrition security projects should explore and encourage amendments to testing, importing, and exporting regulations about legume varieties that are not locally produced to make them more accessible to South African markets, particularly at the local level. Though there have been reports detailing neglected legumes' potential, few have provided a roadmap for exploiting this potential [111]. Thus, there is a need to identify high-potential neglected legumes, prioritize them, and articulate a strategy with actionable recommendations for exploiting the potential of neglected legumes. The development of the strategy should involve the challenges and obstacles, including but not limited to micronutrient deficiency, the unbearable burden of malnutrition, hidden hunger, and opportunities or benefits brought by neglected legume utilization. A guiding framework for addressing the challenges of food and nutritional insecurity should outline coherent actions and activities for future research and development funding on neglected legumes. Lastly, the policies should not be limited to altering food consumption habits and including neglected legumes in the diet to fight against malnutrition, major chronic diseases, and associated risk factors.

14. Conclusions

The importance of neglected legumes in current and future agriculture cannot be understated. They form a minor part of everyday human diets despite their potential to provide a sustainable solution to food and nutritional insecurity, malnutrition, hunger, and their increasingly significant role in improving human health worldwide. Sub-Saharan Africa's food nutritional security requires a major re-focus on neglected legume identification with intensive research on genetic improvement and development to enhance climate-resilient cultivars with improved grain characteristics. Future research on genetic improvement and development should encompass establishing breeding programs to improve the yield, disease resistance, and nutritional quality of neglected legumes; the development of genetic markers associated with desirable traits to facilitate marker-assisted selection and breeding; the application of genomic selection to accelerate the breeding process and improve the accuracy of selection; and the utilization of mutant breeding techniques to induce genetic variation and improve the desirable traits of neglected legumes. Raising awareness and educating farmers, consumers, and policymakers about the neglected legume value and advocating for better utilization in crop rotations while addressing challenges in trade will significantly increase their production over the coming decades and utilization throughout the food system.

As climate change manipulates the environmental and socio-economic drivers of food security, the time has come to rethink and orient policies to sustain neglected legume production and achieve long-term benefits for all communities across the globe. There is a need to promote the cultivation of neglected legumes to sustain food security, especially in the developing countries of sub-Saharan Africa. The policies should not be limited to altering food consumption habits and including neglected legumes in the diet to fight against malnutrition, major chronic diseases, and associated risk factors. Encouragement of neglected legumes' integration into cropping systems and the implementation of specific programs to assist smallholder farmers who are highly vulnerable to climate change could be smart climate adaptation strategies. This will aid in establishing agricultural systems that are resilient and cost-effective with an enormous capacity to improve household livelihoods, nutrition, and food security. Moreover, there is a need for market development and value chains for neglected legumes to improve their availability and accessibility; funding provision for research on neglected legumes to address the knowledge gaps and improve their productivity and utilization; strengthening of extension services to disseminate information and technologies to farmers and consumers on the production and utilization of neglected legumes; incorporation of neglected legumes into school meals and food assistance programs to improve nutrition and promote their consumption; engaging the private sector in the production, processing, and marketing of neglected legumes to improve their availability and accessibility; fostering international cooperation to share knowledge, technologies, and best practices in the production and utilization of neglected legumes.

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