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REVIEW

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Comparison of nutritional values of *Mucuna pruriens* L. (velvet bean) seeds with the most preferred legume pulses

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Abstract

The effectiveness of legumes in overcoming hunger and food insecurity is attributed to their accessibility. They have been recorgnised for their nutritional significance and their ability to provide food stability in tropical and sub-tropical regions. This study compared the nutritional values of *Mucuna* seeds with that of common legume pulses by analysing their percentage composition based on literature review. Similar to common legume pulses, *Mucuna* seeds have been found to contain promising nutritional value. However, unlike most preferred legume pulses, *Mucuna* seeds contain a notable quantity of anti-nutritional factors that interferes with its nutritional qualities. Besides being anti-nutritional, the compounds have bio-active potentials and have been associated with therapeutic and antioxidant activities. Notably, *Mucuna pruriens* L. is known to contain compounds with potential antiparkinsonian effects, such as L-Dopa and ursolic acid. Considering their high productivity and nutritional relevance, *Mucuna* seeds have been utilised as traditional foods in populations with lower incomes that suffer from chronic undernourishment. It should be noted that variations in agro-climatic conditions have been reported to impact the chemical composition of *M. pruriens* seeds. However, limited information on the chemical composition of *M. pruriens* seeds from different regions makes it challenging to compare their composition across various agro-climates. Furthermore, in order to support the widespread use of *M. pruriens* in different areas, further research is needed to determine the optimal conditions for cultivating highly nutritious, phytochemically rich, and commercially viable seeds. Additionally, it is important to evaluate the effectiveness of L-Dopa in treating Parkinsonian patients across a diverse range of populations.

Keywords Legume pulse, *Mucuna pruriens*, Nutritional composition, Anti-nutritional content, Antioxidant activity, Protein-energy deficiency, Human diet

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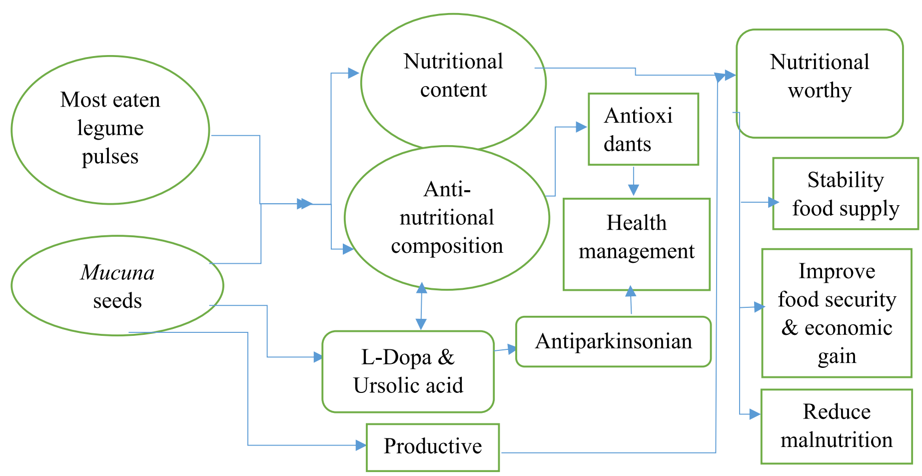
Graphical Abstract



Introduction

Nutrition is an essential fundamental need because it has a significant role in determining health, productivity, and brain development (Vadivel & Janardhanan 2005). Food insecurity, hunger, and hidden malnutrition are increasing in many developing countries as being attributed by rapid population expansion and growing food consumption (FAO et al., 2018). Around 800 million people worldwide are chronically malnourished due to consuming fewer calories per day and experiencing constant or sporadic hunger (McGuire 2015; van Dijk et al. 2021; Webb et al. 2018). Protein-energy deficiency is the most common form of malnutrition in developing countries (Dipasquale et al. 2020). To increase their food supply, several countries are promoting dietary strategies such as introducing high-yielding crops with high nutritional value, long-term preservation, and resistance to pests and diseases (El-Ramady et al. 2022; Webb et al. 2018). *Mucuna* pulses have been acknowledged for their nutritional significance (Pathania et al. 2020). Unlike most consumed legume pulses, *M. pruriens* have characterised as high-yielding crop with valuable nutrients and tolerate a number of biotic and abiotic factors (Sathyanarayana et al. 2016) ensuring its availability throughout the year. Moreover, *M. pruriens* has been recorgnised as a biofertilizer, cover crop, intercrop performance booster, trading good, and food source (Matata et al. 2017; Constantine et al. 2020; Kumiko et al. 2020). Despite their functional food properties, *Mucuna* seeds contain phytochemicals that have potential therapeutic applications (Rai et al. 2020).

Legume pulses belongs to family Leguminosea, are the second-most significant food crop grown in tropics after cereal (Annor et al. 2014; Vadivel & Janardhanan 2005). The pulses are grown, harvested, consumed, and traded as basic goods all throughout the world (Annor et al. 2014). Dietitians advised resuming on consumption of legume seeds (Grela et al. 2017a). United Nations (2014) designated the year 2016 as "the International Year of Pulses" to raise awareness of the benefits of legumes for human nutrition (Vollmann 2016).

The complex carbohydrates found in legume seeds have been linked to improved health, as well as the prevention and management of diabetes and congestive heart failure (James et al. 2020). Additionally, they are good sources of vital minerals, polyunsaturated lipids, and vitamins (Vadivel & Janardhanan 2000, 2005; Ade-Omowaye et al. 2015). Given the adaptability, accessibility and affordability of legumes, it is necessary to explain their nutritional values for the benefit of humankind, especially in areas where protein consumption is insufficient (James et al. 2020). These plant resources can improve the economic situation and food security of local populations (Pongener & Ranjan Deb 2021).

Despite of the nutritional benefits of legume seeds, their utility as food is limited due to their low sulfur-containing amino acid content, poor protein digestibility and the presence of many anti-nutritional compounds (Lampariello et al. 2012; Banti & Bajo 2020). Excessive consumption of these anti-nutritional components may interfere with the body's ability to absorb nutrients and lead to nutritional deficiencies (Banti & Bajo 2020). Anti-nutritional compounds can be harmful and have adverse physiological effects that may result in illness (Huisden 2008; Lorenzetti et al. 2010). In an improperly processed diet, *Mucuna* seeds, can cause gastrointestinal disturbances and have harmful side effects due to the presence of L-Dopa in high level (Lorenzetti et al. 2010; Maillot et al. 2022).

Besides their negative effects, most anti-nutritional factors function as antioxidants in the body by delaying, inhibiting, or eliminating oxidative spoilage to targeted molecules (Suleman, et al. 2019). Common bioactive chemicals in legume pulses include phenolic compounds, flavonoids, carotenoids, polyphenols, terpenoids and L-Dopa compounds, particularly they are helpful in managing and treating health disorders (Enujiugha 2010; Grela et al. 2017a; Tomar et al. 2018; Rai et al. 2020). Contrary to the common legumes, *Mucuna* seeds have a rather high level of the therapeutic anti-nutritional compound L-Dopa (Pulikkalpura et al. 2015). It is employed as an antivenomous in many developing nations, including India (Fung et al. 2009, 2011). Moreover, Parkinson's syndrome may be treated with the medicinal properties of a high concentration of L-DOPA available in *Mucuna* seeds (Longhi et al., 2011; Rane et al. 2019; Pathania et al. 2020; Suryawanshi et al. 2020; Misra et al. 2021). Ursolic acid, another important bioactive element in *Mucuna* seeds, is applied in several therapeutic potentials, including anti-parkinsonian effects, along with L-Dopa (Yadav et al. 2017; Rai et al. 2019, 2020).

Since the human body is unable to produce these healthy plant-based phytochemicals (Kumar & Pandey 2013), it is important to consume them through a properly processed diet and supplements. The most effective processing technique for seed consumption is thermal treatment, as most anti-nutritional factors are sensitive to heat (Aware et al. 2019). Adequate processing eliminates their toxicity and establishes *M. pruriens* seeds as a substantial food source, like the most consumed legumes.

The goal of this review is to demonstrate the potential application of *Mucuna* seeds as a food source, like other common legumes, with a focus on their nutritional profile and antioxidant potential. It is suggested that based on their overall nutritional and chemical properties, *M. pruriens* seeds can be investigated as a supplement for poor populations, providing bioactive compounds and protein. The agro-climate has an impact on the variations in the chemical composition of legume pulses (Kalidas & Mohan 2011), but limited data in some growing regions hinder the comparison of their chemical makeup. Due to many beneficial properties of *Mucuna* seeds compared to the most consumed legume pulses, there should be an in-depth discussion on their nutritional composition, therapeutic potential, and antioxidant properties. The environmental effects and processing techniques on the chemical properties of *Mucuna* seeds should also be highlighted.

Common cultivated food legumes

Some legumes commonly grown and consumed in tropical and subtropical countries include common bean, soybean, groundnut, bambara nut, cowpea, pigeon pea, common pea, chickpea, green gram bean, and the less common *M. pruriens* (velvet beans) (Mnembuka & Eggum 1995; Palilo et al. 2018; Constantine et al. 2020; Kumiko et al. 2020). The common bean (*Phaseolus vulgaris*) is the primary legume cultivated in most regions of the world. In Tanzania, currently the yields of *P. vulgaris* account for about 80% of total legume production, hence contributing to food security and financial gain (Katungi et al. 2019). However, its production is low, with an average yield of less than 500 kg/ha, requiring mineral fertilizers. The reasons for these low yields include high susceptibility to pests and diseases, depleted fields, drought, low seed quality, and poor weed management (Hillocks et al. 2006).

On the other hand, *M. pruriens* (velvet bean) is a promising legume that exhibits fair resistance to various environmental stresses and possesses strong nutritional properties (Pugalenthi et al. 2005). *Mucuna* is capable of consistent yields under dry farming conditions and low soil fertility, making it economically viable when other food legumes may not be feasible (Siddhuraju et al. 2000). It is considered one of the most productive legumes globally, with 5 to 6 seeds per pod and yields reaching 1.5 to 2 t/ha (Fujii et al., 1991). In comparison to commonly cultivated legumes, velvet bean seeds are large in size and heavier, averaging 2.6 g per seed. These seeds have a long viability period, are resistant to pests, and exhibit higher germination rates even in unfavorable conditions (Siddhuraju et al. 2000). Legumes have been utilised in sustainable agriculture to improve food security and combat poverty, hunger, and malnutrition. In many tropical regions of low-income countries, legumes, including *M. pruriens* var *utilis*, are grown for various purposes such as soil restoration, green manure, cover crops, income generation, fodder, and food security (Siddhuraju et al., 2000; Wabwoba, 2019). They are often cultivated as intercrops with maize to enhance overall yields (Hillocks et al. 2006; Palilo et al. 2018). Legumes contribute to soil quality improvement through effective mycorrhizal interactions and the production of significant biomass during decomposition (Saria et al. 2018). Therefore, they aid in rehabilitating depleted fields, increasing soil biodiversity, and enhancing soil productivity.

Nutritional composition of pulse legumes

When compared to animal goods, legume pulses are a good source of reasonably priced plant nutrients and bioactives that are crucial for a human diet. Around 65% of the protein consumed by humans worldwide comes from plants, with grains accounting for 45% to 50% and legumes or vegetables for 10% to 15% (Pongener & Ranjan Deb 2021). The nutritional profile of common legume pulses grown around the world is described in the results listed in Table 1 below. These findings highlight the main chemical components of legume pulses, namely crude protein and carbohydrates, which emphasize their nutritional significance for dietary needs and food security. The energy value of legume seeds ranges between 1497–2384 kJ/100 g DM due to their reasonable quantity of protein, carbohydrates, and lipids while the protein content of beans contributes 20–30% of the energy (Banti & Bajo 2020). Except for groundnuts, soybeans, and chickpeas, the lipid content in other common legume pulses is relatively low and contributes less than 5% of the energy in the diet (Banti & Bajo 2020). The interaction between lipids and carbohydrates is observed, where winged bean and soybeans have very low carbohydrate amounts of 3.00% and 1.33% respectively. On the other hand, green gram, bambara nut, pigeon pea, field beans, and cowpea have high carbohydrate contents of 38.54%, 45.02%, 40.53%, 36.30%, and 41.34% respectively (Mnembuka & Eggum 1995). Additionally, literature have shown a significant ash content in legumes which suggests that they are a superior supplier of minerals (Pugalenthi et al. 2005; Banti & Bajo 2020).

Nutritional composition of Mucuna pruriens (velvet bean) seeds

The nutritional value of *Mucuna* seeds from different geographical locations has been reviewed and is summarized in Table 2 below. These bean seeds are known for their significant protein content and incorporating them into the diet can greatly increase daily protein intake. This is one of the reasons why they have traditionally been used as food in many countries (Pugalenthi et al. 2005). The findings consistently show a relatively low lipid content, below 9.6%. The lipid concentration in a legume seed is influenced by the availability of carbohydrates. With lower lipid levels generally corresponding to higher carbohydrate content and vice versa (Vadivel & Janardhanan 2000). The carbohydrate content in *Mucuna* seeds ranges from 49.9% to 64.88%, and this has a significant impact on the caloric value of the diet. The energy value of a food item is greatly influenced by the concentrations of lipids, carbohydrates, and proteins, and can be estimated by multiplying these concentrations with factors of 37.7, 16.7, and 16.7 respectively (Siddhuraju et al. 1996). The findings indicate that the caloric value of the reviewed *Mucuna* seeds ranged from 1591 to 1990 kJ/100 g DM. Research findings suggest that *M. pruriens* seeds have a nutritional value comparable to that of the most consumed legume pulses.

Anti-nutritional properties of legume seeds

Anti-nutritional compounds are substances that can affect the nutritional value of a food plant and sometimes limit its consumption. Table 3 provides a list of the anti-nutritional composition in various commonly consumed legume pulses. Cowpeas were found to have the highest phenolic content (1.26 g/100 g), while pigeon peas had the lowest value (0.07 g/100 g) (Tomar et al. 2018). Common beans, peas, chickpeas, and lentils showed moderate phenolic compositions of 0.4, 0.2, 0.49, and 2.39 g/100 g respectively (Grela et al. 2017a). Lentil pulses were reported to have high levels of tannins, while other legume pulses exhibited moderate levels, with common beans having the lowest level (Grela et al. 2017a). Grass

Table 1 Nutritional characteristics of most common legume seeds

Legumes (%)	Moisture (%)	Crude Protein (%)	Crude Lipids (%)	Crude fiber (%)	Ash (%)	Carbs (%)	Calorific value KJ100g^{-1} DM	Reference
A	9.0–12.75	13.25–29.34	5.87–34.63	2.23–6.11	4.63–9.82	7.34–64.75	NI	(James et al. 2020)
B	NI	19.0–41.81	3.0–22.88	10.26–3.81	3.53–5.69	1.3–45.02	1878–2384	(Mnembuka & Eggum 1995)
C	7.03–11.67	21.62–28.12	1.33–2.43	3.09–4.66	2.84–4.66	63.17–68.96	1570.33–1606.27	(Khattab et al. 2009)
D	5.7–8.5	20.3–35	3.1–7.4	5.9–10.8	3.4–5.1	49.2–61.8	1497–1626	(Vadivel & Janardhanan 2005)

Values in range indicated in every row involve the quantity of parameter in all studied legume seeds in a particular literature. A = African bread fruit seeds, bambarra nuts, red bean, pigeon pea, cowpea, African yam bean seeds and groundnuts. B = winged bean, soya bean, green gram, bambarra nuts, pigeon pea and cowpeas. C = cowpeas, kidney beans and common pea. D = jack beans (*Canavalia ensiformis*), sword bean (*Canavalia gladiata*) and Senna (*Cassia floribunda*)

Carbs Carbohydrates, *NI* Not investigated, *DM* Digestible and Metabolized energy

Table 2 Nutritional composition of *M. pruriens* (velvet bean) seeds

Velvet beans	Moisture (%)	Crude Protein (%)	Crude Lipids (%)	Crude fiber (%)	Ash (%)	Carbs (%)	Energy KJ100 g^{-1} DM	Reference
M_1	NI	24.31–33.55	4.47–5.35	6.1–9.04	3.4–4.7	51.23–57.85	1920–1990	(Siddhuraju et al. 2000)
M_2	5.6–10.8	21.2–22.3	7.3–11.2	9.2–12.1	2.7–4.1	53.1–59.1	1620–1682	(Vadivel 2019)
M3	6.7–8.5	20.2–29.3	6.3–7.4	8.7–10.5	3.3–5.5	49. 9–61.2	1562–1591	(Vadivel & Janardhanan 2000)
M_4	6.5–8.5	21.2–32.4	5.7–9.6	7.8–12.1	2.7–4.2	50.6–54.4	1593–1625	(Vadivel & Janardhanan 2005)
M_5	8.4–10.68	23.76–29.74	8.24–9.6	6.54–7.6	4.78–5.3	56.56–63.88	1783.02–1791.6	(Tresina & Mohan 2013)
M_6	10.25–10.85	28.75–29.53	8.04–8.26	8.66–8.68	4.22–5.72	NI	1602.98–1623.75	(Daffodil et al. 2016)
M_7	8.79–10.0	24.5–29.79	4.72–7.28	3.65–4.43	3.19–4.16	59.2–64.88	1664–1717	(Ezeagu et al. 2003)

The indicated range of the parameter in every row include the value of all studied legume seeds in a particular literature. M_1 = *Mucuna pruriens* var *pruriens*. M_2 = *Mucuna monosperma*. M_3 = *Mucuna pruriens* (Velvet bean). M_4 = *Mucuna monosperma, Mucuna pruriens* var *utilis* and *Mucuna pruriens* var *pruriens*. M_5 = *Mucuna deeringiana, Mucuna pruriens* var *pruriens* and *Mucuna pruriens* var *utilis*. M_6 = *Mucuna deeringiana* and *Mucuna pruriens* var *utilis*. M_7 = *Mucuna deeringiana, Mucuna pruriens, Mucuna jaspeada, Mucuna preta, Mucuna ghana, Mucuna rajada, Mucuna georgia, Mucuna utilis, Mucuna Veracruz* and *Mucuna cochin-chinensis*

Table 3 Anti-nutritional composition of common legume pulses

Legumes pulses	TP (g/100 g)	Tannin (g/100 g)	Trypsin inhibitor (TIU/mg)	Reference
L_1	0.20–0.45	0.15–0.87	2.62–129.3	(Grela et al. 2017a)
L_2	0.35	0.23–0.14	NI	(Daffodil et al. 2016)
L_3	0.07–1.264	NI	NI	(Tomar et al. 2018)
L_4	0.123–0.148	0.052–0.314	NI	(Heiras-palazuelos et al. 2013)
L_5	0.3497–1.554	NI	3.14–15.72	(Giuberti et al. 2019)

The indicated range of the parameter in every row include the value of all studied legume seeds in a particular literature. L_1 = pea, chickpea, lentil, grasspea, common bean and broad bean. L_2 = *Cajanus cajan* (pigeon pea). L_3 = mung bean, black gram, pigeon pea, cowpea. L_4 = chickpea, L_5 = *Phaseolus vulgaris* (common bean)

TP Total phenolics

peas were found to have a high level of trypsin inhibitors (129.3 TIU/mg) (Grela et al. 2017b), whereas cowpeas had a lower level (0.37 TIU/mg) (Mwasaru et al. 1999).

Anti-nutritional composition of Mucuna seeds

Mucuna seeds contain a significant amount of anti-nutritional compounds, as indicated in Table 4 below. These compounds are considered harmful and restrict the consumption of *Mucuna* seeds compared to common legume pulses (Ezeagu et al. 2003). However, when consumed at safe levels, these seeds may have potential benefits for sustaining, improving, and restoring health (Huisden 2008; Jimoh et al. 2020). Studies conducted on *Mucuna* seeds from different geographical areas have shown variations in their anti-nutritional composition. Research by Sardjono et al. (2017) highlights the presence of L-Dopa in high concentrations compared to other compounds. Significant levels of total phenols, tannins, and trypsin inhibitors have been observed in different varieties of *Mucuna* species from various regions around the world. These variations may be attributed to differences in growing conditions and seed variety (Kala et al. 2010).

Anti-oxidative properties of Mucuna pruriens

Mucuna seeds contain phytochemicals that have potential anti-nutritional properties but can play a significant role in antioxidants and anti-inflammatory effects when consumed at safe levels. These seeds are rich in various bioactive compounds, including polyphenols, alkaloids, saponin, flavonoids, carotenoids, ascorbic acid, gallic acid, ursolic acid, serotonin, and L-Dopa (Lampariello et al. 2012; Rai et al. 2019; Rudra et al. 2020). These compounds have a wide range of therapeutic applications and exhibit anti-oxidative properties (Rai et al. 2017b). They have been found to have potential antiparkinsonian effects by scavenging free radicals and reducing the likelihood of oxidative stress-related disorders (Rai et al. 2019). L-Dopa and ursolic acid are particularly useful in treating Parkinson's disease as they can cross the blood-brain barrier and prevent the degeneration of dopaminergic neurons as a result of

Table 4 Anti-nutritional composition of Mucuna seeds

Velvet bean	L-DOPA (g/100 g)	TP (g/100 g)	Tannin (g/100 g)	Trypsin inhibitor (TIU/mg)	Reference
I	4.1–4.5	2.2–3.3	0.4–0.6	62.5–68.3	(Vadivel 2019)
II	5.98–6.98	3.44–4.95	0.03–0.06	40.72–48.23	(Vadivel & Janardhanan 2000)
III	4.24–6.86	0.85–3.18	0.03–0.06	NI	(Mohan & Janardhanan 1995)
IV	6.35–7.97	2.74–5.24	0.16–0.31	42.02–46.16	(Tresina & Mohan 2013)
V	3.6–4.7	5.2–6.1	0.28–0.55	13.78–15.89	(Siddhuraju et al. 2000)
VI	4.00–8.34	NI	1.56–1.7	30.81–51.55	(Ezeagu et al. 2003)
VII	0.58–6.42	AV	AV	AV	(Pulikkalpura et al. 2015)
VIII	7.56–13.9	NI	NI	NI	(Sardjono et al. 2017)

The indicated range of the parameter in every row include the value of all studied legume seeds in a particular literature. I = *Mucuna monosperma*. II = *Mucuna pruriens* (Velvet bean). III = *Mucuna pruriens* var. *utilis* and *Mucuna monosperma*. IV = *Mucuna deeringiana, Mucuna pruriens* var *pruriens* and *Mucuna pruriens* var *utilis*. V = *Mucuna pruriens* var *pruriens*. VI = *Mucuna deeringiana, Mucuna pruriens, Mucuna jaspeada, Mucuna preta, Mucuna ghana, Mucuna rajada, Mucuna georgia, Mucuna utilis, Mucuna Veracruz* and *Mucuna cochin-chinensis*. VII = 30 accessions of *Mucuna pruriens*. VIII = *Mucuna pruriens* seeds

TP Total phenolics, *NI* Not investigated, *AV* Available

exposure to neurotoxins (Pulikkalpura et al. 2015; Rai et al. 2019). *Mucuna* seeds have been found to be beneficial at the cellular and signaling levels, particularly in neuro-inflammatory mechanisms (Gordon et al. 2012). Antioxidant compounds can undergo oxidation and impact cell signaling (Poljsak et al. 2021). The seeds are rich in potent antioxidants that modulate cell signaling pathways in response to the effects of oxidative stress on dopaminergic neurons (Rai et al. 2017a). In this context, *Mucuna* seeds offer neuroprotection and help maintain the proper functioning of the mitochondrial electron transport system (Zahra et al., 2022). Apart from their antiparkinsonian properties, *Mucuna* seeds also have various other health benefits, such as anti-venom effects (Fung et al. 2012), anti-inflammatory properties (Habtemariam 2019; Rane et al. 2019; Avoseh et al. 2020), anti-epileptic and antimicrobial effects (Rai et al. 2017b). Additionally, the seeds display anticancer, antidiabetic, skin protection, anti-anemia, and antihypertensive properties (Rai et al. 2020).

Toxicity effects of Mucuna

All chemical substances can be toxic when consumed above a certain threshold level. The harmful effects of *Mucuna* species have been reported in leaves, pods, and seeds. The presence of mucunain protein in the hairy pods causes itching and significantly limits the acceptance of *Mucuna* as a food crop (Heuze et al. 2015). The levels of L-Dopa in leaves and pods are relatively low compared to mature dry *Mucuna* seeds, which can have adverse effects when consumed (Huisden 2008; Maillot et al. 2022). Ingesting high amounts of L-Dopa can be potentially toxic (Huisden 2008; Sardjono et al. 2017; Maillot et al. 2022). It has been found to be toxic even in small amounts in individuals with a deficiency of the glucose-6-phosphate dehydrogenase enzyme, leading to induced hemolytic anemia (Kosower & Kosower 1967). Additionally, L-Dopa has been associated with hallucinations and severe gastrointestinal disturbances, including nausea, vomiting, and loss of appetite (Lorenzetti et al. 2010; Aware et al. 2019). One of the reasons for these adverse effects is the conversion of L-Dopa into its oxidized form, dopamine, in the peripheral nervous system (Pulikkalpura et al. 2015).

Environmental effects on chemical makeup of legume pulses

The chemical composition of food legume seeds can vary in different tropical regions of the world. These variations are attributed to differences in agro-climatic conditions and genetic diversity (Kalidas & Mohan 2011; Heiras-Palazuelos et al. 2013). In response to environmental stresses, plants secrete and accumulate anti-nutritional factors as an adaptive mechanism (Lorenzetti et al. 2010). Furthermore, the profile of anti-nutritional composition in legume seeds can vary due to differences in genetic constitution, species, and varieties, as well as differences in climatic and environmental conditions (Lorenzetti et al. 2010). Under certain circumstances, plants need to accumulate anti-nutritional substances to survive and complete their life cycles, however, these compounds can undoubtedly affect the nutritional profile of legume seeds and have unfavorable side effects when ingested (Banti & Bajo 2020).

Effects of processing Mucuna seeds

Anti-nutritional effects in *Mucuna* seeds can be reduced through valuable processing techniques (Nwaoguikpe et al. 2011; Obi & Okoye 2017; Nwajagu et al. 2021). When preparing *Mucuna* seeds as food, hydrothermal processing is a sensible and efficient technique (Aware et al. 2019). Most of the anti-nutritional factors present in legume seeds are heat-labile, which means their toxicity can be eliminated through ordinary cooking processes (Josephine & Janardhanan 1992). The heat-stable L-Dopa in *Mucuna* seeds is typically detoxified by heat treatments such as repeated boiling in water, which is then discarded before further processing (Lorenzetti et al. 2010). While this process can be tedious, involving around eight cycles of boiling and draining until the cooking water changes from black to milky white, it renders *Mucuna* seeds non-toxic and suitable for consumption (Kalidas & Mohan 2011).

Cooking is effective in removing anti-nutritional factors, although it may also reduce the seeds' anti-oxidative properties and nutritional content (Nwaoguikpe et al. 2011; Aware et al. 2019). Thermal denaturation and solubilisation of certain nitrogenous substances during processing can influence the reduction of protein content in processed seeds (Adebowale & Lawal 2003; Nwaoguikpe et al. 2011; Nwajagu et al. 2021). However, heating *Mucuna* seeds changes the functional characteristics of proteins by reducing solubility and emulsibility while enhancing flavor, sugar content, water-holding capacity, and interactions with other food ingredients in a food system (Mugendi et al. 2010a). Hydrothermal processing of legume seeds has been associated with an increase in radical scavenging activity due to thermal degradation of inactive compounds into bioactives (Xu & Chang 2008). Therefore, thermal treatment of *Mucuna* seeds improves the digestibility of proteins and carbohydrates but can also impact their structural and functional properties (Aware et al. 2019). It is worth noting that, the nutritional value of proteins in the diet is enhanced by their digestibility.

Discussion

Food can be functionally tested to determine if it contains the recommended amounts of various macro-molecules and micro-molecules. This review has identified the nutritional role of *Mucuna* seeds, which is comparable to that of the most consumed legume pulses. The reviewed research has shown that the moisture content of *Mucuna* seeds and other popular legume seeds is below 12.72%. However, common bean seeds (*P. vulgaris*) have been found to have higher moisture content ranging from 13.29% to 17.15% (Palilo et al. 2018). Moisture content of ≤ 13% indicates favourable conditions for long-term storage of food substances (Emmanuel et al., 2011). Both *Mucuna* seeds and common legume pulses have relatively similar protein content, although some lower values have been reported for common legume pulses (James et al. 2020). While the protein content in *Mucuna* seeds is lower than that of soybeans (41.81%) and winged beans (38.31%), it is comparable to the protein content in cowpeas, field beans, and pigeon peas (Mnembuka & Eggum 1995). All legume seeds contain protein levels that meet the daily protein needs of adult human beings, as recommended by the USA National Research Council (1974). With regards to lipid content, *Mucuna* seeds have relatively high lipid content compared to cowpeas (1.36–2.07%), kidney beans (1.33–1.83%), and peas (2.23–2.43%) (Khattab et al. 2009). However, this lipid content is still lower than that reported in African oil beans (18.50%) and groundnuts (34.63%) (James et al. 2020), as well as in groundnuts (25.3%) and soybeans (19.5%) (Narasinga Rao et al., 1989). The low lipid content of beans, including *Mucuna* seeds, contributes to their cholesterol-lowering ability, making them beneficial for the prevention and treatment of cardiovascular diseases (Martino et al. 2012). Both *Mucuna* seeds and common legume pulses exhibit a wide range of fiber content, which is a desirable quality for human diets. The recommended intake of fiber by the World Health Organization is 22–23 g per 1000 kcal of diet (Narasinga Rao et al., 1989; Vadivel & Janardhanan 2005). Although it lacks nutritional significance, dietary fiber enhances food digestibility, reduces blood cholesterol levels, and lowers the risk of bowel and breast cancer (Waddell & Orfila 2022). The ash content in both *Mucuna* seeds and common legume pulses falls within the range of 2.7–5.1%, indicating that legumes serve as a good source of minerals (Vadivel & Janardhanan 2005). The carbohydrate levels in *Mucuna* seeds have been found to be comparable to cowpeas (68.96%) and higher than the levels reported in African oil beans (35.12%) and groundnuts (7.34%) (Khattab et al. 2009; James et al. 2020). The energy values of *Mucuna* seeds are not significantly different from those of the most common legume pulses, although soybeans have the highest energy value (2383 kJ/100 g) (Mnembuka & Eggum 1995). Pulses from *Mucuna* plants and other legumes have been found to have a significant anti-nutritional composition (Siddhuraju et al. 2000; Daffodil et al. 2016; Alaye et al. 2020), which also exhibit antioxidant effects when consumed as part of a diet. In addition to these anti-nutrients, *Mucuna* seeds contain L-Dopa (a non-proteinous phenolic amino acids) and ursolic acid (penta-cyclic triterpenoid), which are considered key medicinal chemical constituents (Rai et al. 2017b). The highest level of L-Dopa has been reported in *M. pruriens* seeds from Indonesia, while lower levels have been found in seeds from India (Sardjono et al. 2017; Pulikkalpura et al. 2015). Apart from their nutritional role, *Mucuna* seeds have been recorgnised for their favourable physiological effects, primarily attributed to L-Dopa and ursolic acid. The antioxidant strength of L-Dopa is even stronger than that of widely used standard ascorbic acid (Longhi et al. 2011). Since the body is unable to produce these principal natural antioxidants, it is important to include them in the diet at safe levels (Kumar & Pandey 2013).

Adequate processing can eliminate the toxicity of antinutritional factors in *Mucuna* seeds and establish them as a substantial food source, like other commonly consumed legumes (Alaye et al. 2020). However, processing seeds can lead to a loss of nutrients and phytochemicals, reducing the antioxidant and nutritional qualities of the food (Mugendi et al. 2010a, b; Nwaoguikpe et al. 2011). Heat treatment, despite its benefits in reducing anti-nutrients, can also impact the nutritional value by significantly reducing the number of soluble vitamins present in the seeds (Banti & Bajo 2020). It has been observed that heating induces a loss of vitamins by 25–30% (Huisden 2008).

Conclusions

The reviewed literature highlights the nutritional potential of *Mucuna* seeds, placing them on par with commonly cultivated legume pulses and emphasizing their importance in the traditional diets of developing countries. When properly processed, *Mucuna* seeds have the potential to serve as functional and therapeutic foods. These plant species are valuable sources of proteins, lipids, carbohydrates, dietary fiber, vitamins, and minerals that are essential for human health. They also contain bioactive compounds such as tannins, phenolics, L-Dopa, ursolic acid, and vitamins, which exhibit strong antioxidant properties. These compounds have the potential to enhance human health and reduce the risk of lifestyle diseases. Therefore, the cultivation of legume pulses, including *M. pruriens*, should be encouraged not only as a meat replacement but also as a component of a balanced and nutritious diet for various groups of people. However, many individuals are unaware of the nutritional value and significance of *M. pruriens* L in different geographical regions since, geographical location plays a significant role in the chemical composition of food plants. Despite the anti-nutritional composition of *M. pruriens*, proper processing can eliminate their toxicity and establish the seeds as a substantial food source, similar to the most commonly consumed legumes. It is crucial to explore efficient processing techniques that can retain the recommended level of phytochemicals, as well as the nutritional value and stability of protein preparations when consuming *Mucuna* seeds. Furthermore, *M. pruriens* seeds could be researched as a supplemental protein source for a significant population and potentially provide additional benefits if the effectiveness of L-Dopa is tested on a broad range of Parkinson's disease patients.

Abbreviations

L-Dopa	L-3, 4-dihydroxyphenylalanine
DM	Digestible and Metabolized energy

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Authors' contributions
FB Participated in origination of idea on nutritional profile of *Mucuna pruriens* seeds as related to the most eaten common legumes pulses, designing, writing and submission of the manuscript. WBW Organization of manuscript, editing of the manuscript, interpretation of relevant literature and revised the manuscript critically for important intellectual content. SN Origination of nutritional value of food plants in Tanzania, conducted research on nutritional content, anti-nutritional composition and antioxidant activity in varieties of food plants. All authors proofread the work before submission.

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Availability of data and materials
All data supporting this study and its supplementary information are openly available online in a google scholar. Nutritional and anti-nutritional composition of legume pulses are provided in Tables 1, 2, 3 and 4 along with original references describing the nutritional and anti-nutritional levels used in this study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interest.

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