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MINIMUM WATER CONSUMPTION METHOD SCREENING OF VELVET BEAN (MUCUNA SP.) PROCESSINGS TO PRODUCE FUNCTIONAL FOOD INGREDIENTS

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ABSTRACT

Velvet bean (*Mucuna* sp.) has been proven containing many beneficial compounds that can be implemented in pharmaceutical and medicines but less noticed for functional foods even though traditionally it is consumed as daily foods or snacks. The indigenous food preparation such as velvet bean Tempe warrants scientific investigation to help society with better public health management. The objective of the review is to select the best method for functional food ingredient product development using velvet beans and provide hypothetical health-oriented food processing e.g. velvet bean flour as functional food ingredients with a focus on less water consumption during processing. Steaming is the selected method.

Keywords: *Food ingredient, functional food, lower water use processing, safe velvet bean*

ABSTRAK

Koro benguk (*Mucuna* sp.) telah terbukti memiliki banyak senyawa yang menguntungkan yang dapat diterapkan dalam farmasetika dan pengobatan tetapi kurang diperhatikan untuk pangan fungsional meskipun secara tradisional dikonsumsi sebagai pangan sehari-hari atau camilan. Penyiapan pangan secara asli seperti tempe koro benguk memerlukan investigasi ilmiah untuk membantu masyarakat dengan pengelolaan kesehatan masyarakat yang lebih baik. Tujuan dari review ini adalah untuk menyeleksi metode terbaik untuk pengembangan ingridien pangan fungsional menggunakan koro benguk dan memberikan hipotesa pengolahan pangan yang berorientasi kesehatan, misalnya, tepung koro benguk sebagai ingredien pangan fungsional dengan fokus pengolahan yang sedikit memerlukan air. Pengukusan sebagai metode yang dipilih.

Kata kunci: *Ingredien instan, koro benguk yang aman, pengolahan dengan sedikit air, pangan fungsional*

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INTRODUCTION

Velvet beans, Mucuna genus, has recently become important and it seems progressively being explored for potential foods with beneficial health effects so the genus members are potential functional food resources. It has almost been four decades the intensive research on *Mucuna sp.* revealing various aspects, ultimately those of nutritional and health effects, antinutrients, and processing types. The abundant data yet is awaiting to be optimally used to support sustainable healthy living and to fixing the degrading agricultural system for livelihood. Velvet bean is a well-known covering crop to replenish humus and nitrogen fixation as green manures in the farming area. Moreover, mucuna showed the capability to extract >30% of soil hydrocarbon into leaf (Nwaichi *et al.*, 2009) and recommended as decontaminator plant to tackle oil spills in the land (Eucharia and Edward, 2010). Although L-DOPA is released into the soil as a weed controller by mucuna affecting the growth of other plants, its allelochemical effects lose after 12 weeks postharvest period tested using *S. stenocarpa* (Eucharia and Edward, 2010).

There are two velvet bean climbing characteristics, i.e. woody and herbaceous; totally, it is comprised of around 105 species in the world either growing in tropical or subtropical regions (Ingalhalikar *et al.*, 2017). The woody velvet bean is more likely to be newcomers whose different types of pods, seed shapes, and general floral colors. *M. laticifera*, *M. macrocarpa*, and *M. birdwoodiana* are those belong to woody velvet bean whereas herbaceous velvet bean are *M. pruriens, M. utilis*, and many others which have been explored earlier for foods and medicines. Hence, *Mucuna sp.* truly still becomes interesting research subjects besides the abundant research already obtained since the 1970s. Historically, one of the ancient documents about velvet bean in Indonesia was pessimistic about the possibility of good uses of velvet bean along with human's experiences in interactions with velvet bean (Heyne, 1987) because at that moment (Colonialism) they mostly used velvet bean plant for green manures in the farms while the leaves and seeds were consumed or used as part of traditional medicine by native population yet lack of scientific data. Therefore, various experiments were carried out starting from green manure, in vivo for cattle feeds to scientific investigation on traditional medicines. But, now velvet bean has obtained much attention for its previously negative effects on human life through a new concept of functional food or health-oriented food. The compounds responsible for various symptoms such as vomiting, headache, or itchiness have been revealed in studies in many countries.

Indigenous processing methods are the best resources to screen the goals of this research. Vadivel and Bielsaski (2012) evaluate indigenous processing of velvet bean from India for velvet beans collected from around the world (Mexico, India, USA, Zimbabwe, Nigeria, Benin, Guatemala, Ghana, Kenya, and Guinea) and found such processing is safe to be applied continuously as food base products at the household level, not as drugs. Nowadays, in Indonesia velvet bean varieties are still cultivated generally in suboptimal areas where water and/or clean water scarce. The ancients documents indicate velvet bean species found in Indonesia namely: (a) *M. diabolica* Backer, (b) *M. junghuhniana* Backer (*M. blumei* Burck), (c) *M. pruriens* DC (*M. prurita* Hook.), (d) *Spatholobus ferrugineus* Benth, (e) *Spatholobus littoralis* Hassk., (f) *Calopogonium mucunoides* Desv., and (g) *M. bakeri* KDS (Heyne, 1987). This is still apparent to be cultivated.

Nevertheless, until now velvet bean is underutilized crops due to its antinutrients, toxin and itching characteristics of its hairs. Antinutrients in velvet bean include tannin, digestibility enzymic inhibitors (antitrypsin, antiamilase), phytates, and antihemagglutinin. Based on the names, it describes what kind of crops velvet bean is. For instance, devil bean, *pruriens* which is in Latin referring to "itching sensation" from the fine hairs (Sridhar and Bhat, 2007) covering velvet bean pods. The pods have hairs containing 5-hydroxytryptamine (serotonin) and mucunain (a protein) that cause severe itches (erythema) (Giuliano and Allard, 2001). Yet, behind the negative traits, velvet bean suddenly wakes the world up from its contributions for managing health, venoms, malnutrition for marginal people after Ayurvedic messages revealed. Velvet bean's

uniqueness that grows in arid areas, making it is blessed with so many bullets to survive in such poor soils. In contrast to its comparable nutrition to soybean, antinutrients and alkaloids, cyanides and a non-protein amino acid seem complementarily required by velvet bean to facing a battle in environmental challenges. Velvet bean research, especially those herbaceous, started increasing since its content of L-DOPA (3,4-dihydroxy-L-phenylalanine) found to be capable of treating Parkinson's disease (Shaw and Bera, 1993; Prakash and Tewari, 1999; Pierson *et al.*, 2004). Velvet bean exploration is re-born (Buckles, 1995) but in Indonesia, continuous research on velvet bean kept going on including (a) tempe of velvet bean which is continuously carried out in the Javanese society (Sardjono *et al.*, 2012; Wanita and Rahayu, 2011), (b) plantation of velvet bean (Pramono, 2010), (c) food product development of velvet bean (Sardjono *et al.*, 2012; Wanita and Rahayu, 2011; Sudiyono, 2010), and (d) Pharmacology of velvet beans (Sardjono, 1995; Winarni *et al.*, 2011; Sardjono et al., 2018).

A systematic and comprehensive program has not been done for commercialization activities. It is time to transform the research results into an industrial system from agriculture to public health due to its potential safer protection for land from destructive inorganic fertilizers. It is demanded to enrich the soil with organic matters and selective herbicide to control weeds. Among them, the species of *Mucuna pruriens* as a cover crop widely accepted for enhancement of water infiltration into the soil, softening the soil, improvement of soil fertility and to suppress the weeds (*Acanthospermum hispidum, Euphobia hirta, Senescio vulgaris, Oxygonum sinuatum, Schkuria pinnata, Richardia brasiliensis, Bidens pilosa, Sonchus oleraceae*)(Osei-Bonsu *et al.* 1994; Mwangi *et al.*, 2006). Interestingly, all antinutrients which are water-soluble simply leach out during soaking, rinsing, or washing. However, the arid or semiarid areas also mean that there is not much water available to control the antinutrients to the safe level doses during processing in such areas.

Although intensive research has been done on diverse species of mucuna from various points of view, there are still left problems required to be tackled. Hence, there is an urgent call to fix the food processing that saves nutrients and simultaneously reduces the antinutrients at safe levels but retains L-DOPA content at physiologically functional levels for neural health in the way that uses minimum consumption of water. And current society demands convenience food products so instant food product or food ingredients to support instantaneous characteristics is worthy to be investigated and implemented for sustainable agricultural-based livelihood.

The objectives of this review are (a) to screening from publications a candidate to be developed for minimum water consumption type processing of velvet beans including those studied from ancient documents about velvet bean in Indonesia; (b) to estimate the amount of water for each processing at the similar basis of velvet bean feeding quantity in the processing. Finally, it will recommend the processing type which requires less water for further investigations at scaling up to pilot plant for commercial functional food ingredient production in Indonesia.

MUCUNA PLANT

Taxonomically, velvet bean species belongs to the family of Fabaceae, some referring it with the name of *Stizolobium* (Sridhar and Bhat, 2007). Regarding its excellent chemical composition resembling soybean, velvet bean has been developed for combating malnutrition as well as curing particular diseases by usages of alkaloids in the seeds. The most popular species is *M. pruriens* which has several varieties, e.g. in Indonesia *M. hirsuta* W. and A., *M. utilis* Wall, *M. velutina* HASSK., *M. capitata* W. and A., and *M. cochinchinensis* A, Chev., *M. nivea* W. and A., *Stizolobium niveum* O.K. (Asia Nivea) as well as *M. lyoni* Merr (America lyoni) (Heyne, 1987). The varieties in *Mucuna pruriens* var. *pruriens* produce seeds richer in levodopa (Eucharia and Edward 2010) compared to others that can act as a direct precursor of the neurotransmitter dopamine and strongly affect sexual function (Giuliano and Allard, 2001). The characteristics of velvet seeds are described in Table 1.

Tabel 1. Characteristics of mucuna seeds

	Direct observation	Bhat *et al.* (2008)	Sardjono *et al.* (2012)	Heyne (1987)
origin	Yogyakarta, Indonesia		Yogyakarta, Indonesia	Sumatera, Bali, Java, Molucas, Madura and its small islands, Celebes islands
shape	round-flat	flat or varied	oval and flat	flat, a little bigger than other legumes; very glossy (*M. hirsuta* W. and A.)
color	-grey -yellowish-brown -white -black -white grey spotted -black patterned -brown patterned	black	white, black, white with black dots	white from a purple flower (*M. hirsuta* W. and A.); grey seed coat, white with spots, yellowish pale brown background with brown lines, deep black; big seed and glossy, initially red then dark brown almost black (*M. capita* W. and A.)
weight (g/100 seeds)		43.61±1.06	96.3*	
coat (g)		0.07±0.01		
cotyledon (g)		0.37±0.08		
length (cm)		1.2±0.13	1.491	
diameter (cm)		0.78±0.12	0.682	
thickness (cm)		0.59±0.08		
hilum (cm)		0.44±0.03		
smell	specific velvet beans		characteristics of velvet beans	
taste			bitter	
appearance				parts of plant is covered by fine golden or brown hairs which causes itchiness, glossy in the pods
ethnobotany				many cases indicated headache, vomiting and poor appetite when consumption of velvet bean meals without soaking step; proper processing gives better body weights or good harvest

∗ calculated from single beans

Indonesian sources of velvet bean germplasm is still underexplored and important notes from ancient documents strongly recommend water-intensive uses during food processing. Tempeh making from velvet seeds is still happening in Java in particularly remote areas. Figure 1 shows Mucuna sp. used as tempeh making in Yogyakarta, Indonesia. Exploration for sustainable agricultural-food management in environmentally friendly ways can holistically keep balancing health food requirements and soil maintenance for sustainable agricultural practices.

L-DOPA

All species members of Mucuna sp. have been proven to contain L-DOPA either in seeds, leaves, and other parts of the plant. This compound is grouped into allelochemicals. L-DOPA is a nonprotein amino acid L-3,4-dihydroxyphenylalanine. It is categorized as a product of biotransformation i.e. a single amino acid L-tyrosine is hydroxylated into L-DOPA by tyrosinase (EC 1.14.18.1) in a pathway of melanin biosynthesis (Raval *et al.*, 2012). L-DOPA becomes an active biomolecule different from L-tyrosine. In the velvet bean plant, it is a precursor of many alkaloids, catecholamines, and melanin syntheses and is released into soils, inhibiting the growth of nearby plant species acting as allelochemicals (Soares *et al.*, 2014). As allelochemicals, L-DOPA controls soil and other plant growths (Rogers *et al.*, 2004). L-DOPA resists attacks from insects and thus it can control biological infestation during storage too (Balogun and Olatidoye, 2012). Based on worldwide investigations (India, America, and Africa) on 36-38 mucuna accessions regarding the L-DOPA in velvet eban plant Sridhar and Bhat (2007) concluded that : (1) black seeds contain higher L-DOPA compared to white seeds (Vadivel and Janardhanan, 2000), (2) geographical location of cultivations affect L-DOPA contents, i.e. closer to the equator the seeds contain more L-DOPA (Lorenzetti *et al.*, 1998), and (3) interaction of

genotype and accession is stronger than genotype and geographic location but latitude could affect several accession more (Capo-chichi *et al.*, 2003), furthermore, L-DOPA contents at the early stage of maturation is lower than that of fully mature seeds.

Figure 1. *Mucuna pruriens* currently direct observation found in Indonesia in 2018 (A-C mottled, (D) black, (E) Kaunch, and (F) white.

L-DOPA more likely decreases during the germination of velvet seeds because it is used as N-supply or preparing soil where it is starting to grow. During its growth velvet bean releases L-DOPA into soils and it affects other plants around it as an allelochemical. Then the L-DOPA diffuses out spreading wider due to rains (Ferreira and Janick, 2004) and watering activity thus no weed growths in the area around it. Meanwhile, the allelochemical DOPA can affect other plants through growth suppression decreasing dry matter yields (for *S. stenocarpa* 1.58 g dry matters obtained in control but it became 1.06 g when grows mixed with *M. pruriens* var. *pruriens*), smaller leaf areas, and poor growth rates but not affecting the capacity to germinate (Eucharia and Edward, 2010). L-DOPA suppresses radicle growth but less attacks hypocotyl growth and may ineffectively affect germination (Fujii, 2003). Towards soybean, cucumber, and maize L-DOPA affect its lignin related synthesis in the cell wall because it is effectively absorbed resulting in increased tyrosine, lignin biomarkers, and phenylalanine but its root growth is inhibited. It is categorized as a strong allelochemical with EC_{50} ranges from 5-50 mg/mL. Its herbicidal effects at 1,500 and 3,000 ppm affects wild mustard (*Sinapsis arvense*), creeping thistle (*Cirsium arvense*), filed poppy (*Papaver rhoeas*), and henbit (*Lamium amplexicaule*), but it does not significantly affect wheat and barley through inhibiting root growth (Topa and Kocacaliskan, 2006).

Homeostasis of iron and amino acid metabolism in mammals is also affected by L-DOPA related to ion transporter encoding (Golisz *et al.*, 2011). L-DOPA is converted into dopamine in the brain and body by enzyme L-aromatic amino acid decarboxylase which directly controls the movement of the body (Raval *et al.*, 2012). In patient of Parkinson disease L-DOPA was found to increase incorporation of L-DOPA-protein in lymphocyte cell proteins as a “toxic” situation (Rogers *et al.*, 2004).

Pivotal effects of dose-dependent L-DOPA and its metabolite dopamine on neural-tissues can be described that besides alleviating the disease symptoms, L-DOPA may contribute to disease progression. Acute side effects of L-DOPA, which include nausea, vomiting, and orthostatic hypotension (dizziness), are correlated with plasma levels. It is important to note that dopamine does not pass the blood-brain barrier in sufficient quantities, thus only a small percentage of L-DOPA reaches the brain after systemic administration. Moreover, L-DOPA is quickly metabolized peripherally, therefore high systemic L-DOPA doses are required to achieve the clinical effect (3-4 g of L-DOPA/day). Because immediate

side-effects are directly related to L-DOPA peak plasma levels, L-DOPA was, in recent years, administered in combination therapy with other compounds such as decarboxylase and COMT (Catechol-amine-O-methyl-transferase) inhibitors to prevent peripheral metabolism. To prevent the metabolism of dopamine in the brain, MAO (Mono-amine oxidase) inhibitors were also used. With these additives, it was possible to reduce the daily required dose of L-DOPA to an average of about 600 mg/day. However, these additives were only partially capable of reducing the toxic side effects of the treatment with levodopa and could not prevent disease progression.

In vitro synthesis of L-DOPA from amino acid tyrosine by soil isolate, *Penicillium jensenii* showed the production of alpha methyl DOPA along with L-DOPA. It is proposed that alpha methyl DOPA as a candidate to prevent unmetabolized L-DOPA from intensive L-DOPA metabolism for movement control after transformation into dopamine in the brain. Alpha methyl DOPA will be a delivery facility of unmetabolized L-DOPA so that the injured nerve cells have chances to recover instead of losing L-DOPA for movement intensively (converted into dopamine) (Raval *et al.*, 2012). It may indirectly control the toxic situation by L-DOPA-protein in lymphocyte cells. Fermentation would give a window opportunity to put biotransformation of tyrosine for both L-DOPA and alpha-methyl DOPA for a special goal towards functional foods containing L-DOPA mixed with alpha-methyl DOPA for the diet of Parkinson's sufferers of neural diseases.

VELVET BEAN USES

Velvet bean has intensively been revealed as one of functional food and simultaneously nutraceutical resources from ancient Ayurveda document in India. It is one of the potential pharmaceutical resources for neural related disease, proasidiac, snake bite venom, etc. The potential compounds highly important in pharmaceuticals include 1-methyl-3-carboxy-6,7-dihydroxy-1 2,3,4-tetrahydroisoquinolone, 5-hydroxytryptamine, 5-methoxy-n,n-dimethyltryptamine-n-oxide, 5-oxyindole-3-alkylamine, 6-methoxyharman, Alanine, Arachidic-acid, Arginine, Aspartic-acid, Behenic-acid, Beta-carboline, Beta-sitosterol, Bufotenine, Choline, Cis-12,13-epoxyoctadec-trans-9-cis-acid, Cis-12,13-epoxyoctadec-trans-9-enoic-acid, Cystine, DOPA, Gallic-acid, Glutamic-acid, Glutathione, Glycine, Histidine, L-DOPA, Lecithin, Leucine, Linoleic-acid, Mucunadine, Mucunain, Mucunine, Myristic-acid, N,n-dimethyltryptamine, N,n-dimethyltryptamine-n-oxide, Nicotine, Oleic-acid, Palmitic-acid, Palmitoleic-acid, Phenyalanine, Phosphorus, Proline, Protein, Prurienidine, Prurienine, Saponins, Serine, Serotonin, Stearic-acid, Threonine, Tryptamine, Tyrosine, Valine, Vernolic-acid (Phytochemical and Ethnobotanical Databases at Phytochemical Database, USDA-ARS-NGRL, Beltsville Agricultural Research Center, Beltsville, Md).

The uses of velvet bean are not limited for general foods only because of famine, but also the intentional uses for particular goals regarding health and curing. Traditionally, velvet bean is used as a carminative, hypotensive, and hypoglycemic agent. Moreover, it is also used as anodyne, antidotal, aphrodisiac, diuretic, nervine, resolvent, rubefacient, and vermifuge; used for anasarca, asthma, cancer, cholera, cough, diarrhea, dog bite, dropsy, dysuria, insanity, mumps, pleuritis, ringworm, snakebite, sores, syphilis, tumors, and worms (Divya *et al.*, 2017). Matured beans are consumed widely in Asia such as India, Sri Lanka, Ghana and Nigeria (Sridhar and Bhat 2007), Mozambique and Malawi (Infante *et al.*, 1990; Gilbert, 2002) as well as in Indonesia and, Japan (Higasa *et al.*, 1996) and they are considered as safe (Diallo *et al.*, 2002) food products. These seeds are also reported to be rich in antioxidant properties (Tripathi and Upadhyay, 2001). L-DOPA is also claimed to have a high antioxidant capacity (Raval *et al.*, 2012; Balogun *et al.*, 2017).

NUTRITIONAL PROPERTIES OF VELVET BEAN

The pulished nutritional analysis of velvet beans is presented in Table 3. It can be seen that various mucuna varieties would give relatively similar nutritional provisions for human needs: carbohydrates with a sufficient amount of fibers,

proteins, high minerals (ash), and moderate levels of lipids. Any species of mucuna can be useful germplasm worldwide. Further detailed ash, fatty acids, and amino acid compositions listed in Table 4 - 6 strongly recommend balance nutrients required for any age groups and genders can be obtained from mucuna seed-based food products. Iron minerals exist in all mucuna species indicating that the beans can be good iron sources regardless of the antinutrients in them. The potassium contents are high thus it can be good contributions for diet components for people suffering from heart diseases and blood pressure. Calcium and phosphor with low sodium contents may a good composition for osteoporosis controls. Furthermore, micronutrient minerals such as zinc, cuprum, selenium, and mangan also provide better supply for people with diabetes mellitus problems. Fatty acid compositions indicate that the polyunsaturated-saturated ratios >1 would be less risk for health problems for instance people living with heart diseases. Many essential amino acids are available in velvet beans of different species; indeed, methionine is the least existing amino acid in them, thus diverse foods are recommended.

Table 2. Uses of velvet beans

Velvet bean based food products	Locations	References
velvet bean tempe-meal, dish	Indonesia	Pramono (2010) Harmayani *et al.* (2016) Heyne (1987)
"dage benguk" a spontaneous fermentation product	Indonesia, in the past	
"gedebel benguk" (oncom like product, a fermented legume using *Monilia sitophilia*)	Indonesia, in the past	Heyne (1987)
leafy vegetables from young leaves (*M. hirsuta* W. and A.) and seeds were consumed as foods eaten with rice or uses as part of medicines	Indonesia, in the past	
L-DOPA to relief Parkinson's disease symptoms	na	Shaw and Bera (1993) Prakash and Tewari (1999).
decoction of *Mucuna* seeds lowered plasma cholesterol and lipids in rats	na	Iauk *et al.* (1989)
beverage component or consumed as roasted powder	Kenya	Saha and Muli (2000)
beverage of coffee mucuna powder	na	Diallo *et al.* (2002)
yogurt	Indonesia	Wanita and Rahayu (2010)
beef burger	na	Onweluzo *et al.* (2004)
weaning foods	na	Egounlety (2003)
snack	na	Sridhar and Bhat (2007),
fried velvet bean snack	Indonesia	Sudiyono (2010)
paste or oil soup (stew),	Southern Ghana	
roasted snacks (Akpaka Ide)	Southern Ghana	Osei-Bonsu *et al.* (1996)
sauce (Akpoko ji/nkashi/Una)	Southern Ghana	
gel (Opka),	Southern Ghana	
additives or condiment, e.g. as thickener in sauce or soup, stabilizer gum or gel,	na	Onweluzo *et al.* (2004)
Moi-moi, and fried cake	na	Sridhar and Bhat (2007)
porridge	na	Sridhar and Bhat (2007) Diallo *et al.* (2002),
non soya tempe.	Japan	Higasa *et al.* (1996)
young leaves and pods were consumed as vegetables; sometimes also for cattle feeds	Indonesia	Heyne (1987)
immature pods and leaves serve as vegetables, while seeds as condiment and main dish by ethnic groups	Nigeria	Adebowale and Lawal (2003b)
daily meal, cooked and ground like mashed velvet beans *M.cochinchinensis* and *M. utilis*	Southern Ghana	
After draining the cooked water, softened seeds are hulled, ground into paste and mixed with other ingredients (e.g. chillies, egg plant, onions, meat or fish) to prepare soup (Asadua and Nkwan), which is eaten along with starchy staples.	Southern Ghana	Osei-Bonsu *et al.* (1996)

Table 3. Velvet bean diverse nutritional composition based on worldwide researches

Nutrients	Balogun and Olatidoye (2012)	Balogun *et al.* (2017)	Ravindran and Ravindran (1988)	Bhat *et al.* (2008)	Sardjono *et al.* (2012)	Siddhuraju *et al.* (1996)	Ezeagu *et al.* (2003)	Rajaram and Janardhanan (1991)	Ezeagu *et al.* (2003)	Mohan and Janardhanan (1995)	Afolabi *et al.* (1985)	Ezeagu *et al.* (2003)
origin	Ibadan, Nigeria	Ibadan, Nigeria		India	Yogyakarta, Indonesia							
analyses locations	Nigeria	Indonesia		India	Indonesia							
species	*M. utilis* black	*M. utilis* black	*M. utilis*	*M. pruriens*	*M. pruriens* (L)	*M. pruriens*	*M. cochinchinensis*	*M. gigantea*	*M. jaspeada*	*M. monosperma*	*M. solanei*	*M. veracruz* (black)
proximate (%)												
moisture	6.02±0.11	10.33±0.07	-	9.58±0.38	9.14^{shell} 10.80^{kernel}	-	-	-	-	-	-	-
crude protein	25.65±0.14	22.67±0.33	26.40	23.04±0.38		31.44	29.79	30.62	27.56	23.50	24.00	24.50
crude lipid	$14.52±0.05^{ether}$	$2.12±0.11^{hexane}$	4.10	7.13±0.17		6.73	6.51	9.03	4.72	14.39	6.50	6.90
fatty acids$^{0.86xfat}$	12.49		-	-		-	-	-	-	-	-	-
ash	3.60±0.01	3.94±0.02	3.70	4.79±0.72	2.18^{shell} 3.04^{kernel}	4.11	4.16	5.99	3.25	3.21	3.00	3.66
carbohydrate	42.98	60.23	59.50	57.18±0.93	-	52.56	59.54	42.54	64.47	52.20	ND	64.88
crude fiber	7.23±0.05	-	6.30	7.85±0.04	-	5.16	4.19	-	4.43	6.79	5.30	4.27
in vitro protein digestibility	-	-	-	50.65±5.42	-	-	-	-	-	-	-	-

Table 4. Mineral compositions

	Balogun and Olatidoye (2012)	Ravindran and Ravindran (1988)	Bhat *et al.* (2008)	Mary Josephine and Janardhanan (1992)	Siddhuraju *et al* (2000)	Siddhuraju *et al* (2000)	Ajayi *et al* (2006)	Rajaram and Janardhanan (1991)	Ezeagu *et al* (2003)
spesies	*M. utilis* (black)	*M. utilis*	*M. pruriens*	*M. pruriens*	*M. pruriens* var. utilis white	*M. pruriens* var. utilis black	*M. flagellipes*	*M. gigantea*	*M. jaspeada*
minerals (mg/100 g)									
-Ca	148.88±0.2	250	66.53±0.92	247	87.80	104	12.80	518	80
-Na	54.46±0.2	70.00	6.15±2.03	4.10	12.70	25.70	11.10	35.30	-
-K	1,472.33±0.2	11,110	164±2.15	2,537	1,575	1,343	1,322	2,296	8,460
-Mg	23.66±0.3	110	42±0.4	72.40	120	109	58.30	506	170
-P	377.12±0.2	220	245±11.45	459	499	376	-	194	470
-Fe	3.44±0.2	1.30	14.63±1.05	5.19	5.79	7.47	82	9.42	6,800
-Zn	3.46±0.1	1.00	5.7±1.15	1.71	5.26	12.20	7.30	8.24	4.60
-Cu	0.71±0.1	0.60	2.51±0.01	0.47	2.42	1.65	2.60	1.18	1.82
-Mn	5.28±0.1	1.00	3.03±0.12	0.31	1.49	2.41	11.90	2.36	5.17
-Se	-	-	19.43±4.39	-	-	-	-	-	-

Table 5. Fatty acid compositions

	Balogun and Olatidoye (2012)	Bhat *et al.* (2008)	Siddhuraju *et al.* (2000)*	Siddhuraju *et al.* (2000)*	Siddhuraju *et al* (1996)*	Ajayi *et al.* (2006)*	Mohan and Janardhanan (1995)*
species	*M. utilis* (black)	*M. pruriens*	*M. pruriens* var. utilis white	*M. pruriens* var. utilis black	*M. pruriens*	*M. flagellipes*	*M. monosperma*
fatty acids mg/g lipid							
-palmitic	28.8%**	4.17	2.01	2.18	2.02	1.07	2.46
-stearic	18.21**	0.06	0.71	0.74	0.38	0.34	1.17
-oleic	20.12**	6.82	0.83	0.70	2.87	-	3.08
-linoleic	26.40**	-	4.88	4.80	3.71	1.50	2.47
-linolenic	8.71**	1.42	0.65	0.77	0.33	-	0.47
-behenic	2.42**	0.64	0.34	0.34	0.07	0.14	0.35
-myristic	-	0.07	0.02	0.02	-	-	-
-myristoleic	-	0.01	trace	nd	-	-	-
-elaidic	-	2.16	trace	trace	-	6.07	-
-linoelaidic	-	5.82	-	-	-	-	-
-heneicosanoic	-	0.10	0.01	0.01	-	-	-
-lauric	-	-	trace	-	-	-	-
-arachidic	-	-	0.14	0.45	0.18	-	-
-tricosanoic	-	-	-	0.01	-	-	-
-lignoceric	-	-	0.09	0.09	-	0.39	-
-palmitoleic	-	-	0.03	0.03	0.17	-	-
-linolelaidic	-	-	0.27	0.15	-	-	-
-eicosadienoic	-	-	0.01	0.01	-	-	-
-eicosenoic	-	-	-	-	-	0.23	-
-cerotic	-	-	-	0.01	-	-	-
Oleic:linolenic ratio	2.31**	-	-	-	-	-	-
Polyunsaturated:saturated	-	3.20	2.02	1.83	2.67	3.54	1.51

Table 6. Amino acid compositions

Nutrients	Balogun and Olatidoye (2012)	Bhat *et al.*(2008)	Adebowale *et al* (2005)	Siddhuraju *et al* (1996)	Afolabi *et al* (1985)
amino acid composition g/100 g	*M. utilis* (black)	*M. pruriens*	*M. cochinchinensis*	*M. pruriens*	*M. solanei*c
lysine*	5.72	8.98	6.78	6.60	13.47
histidine*	3.13	3.30	2.36	3.14	1.13
arginine*	7.41	9.55	8.05	7.16	11.81
aspartic acid	14.28	17.10	13.6	8.16	6.94
glutamic acid	13.28	19.31	16.8	17.23	10.03
glycine	5.49	6.21	5.43	5.12	3.08
valine*	4.47	7.60	6.98	5.57	3.65
methionine*	0.69	0.78	1.32	1.28	1.18
isoleucine*	7.24	8.77	9.08	4.12	2.70
leucine*	6.14	10.42	7.27	7.85	5.16
tyrosine	3.94	7.51	5.46	4.76	11.16
cysteine	4.52	1.61	1.04	0.84	1.72
phenylalanine*	4.58	6.51	7.69	3.85	14.81
serine	4.53	6.08	3.45	4.10	3.32
proline	3.64	7.38	13.45	nd	3.30
tryptophan	0.81	ND	2.34	1.35	nd
alanine	4.28	4.95	7.45	2.81	3.61
threonine*	3.86	5.21	5.04	3.64	2.04

*** essential amino acids; **calculated**

VELVET BEAN PROCESSING AND WATER REQUIREMENTS

Sterilization of velvet seeds is important (Bhat *et al.*, 2007) that there was fungi growth on the surface of grains including Aspergillus, Fusarium, Eurotium, and yeast. Precaution should be paid for the toxigenic fungi namely *Aspergillus flavus*, *A. niger*, and Fusarium sp. by which irradiation at 10 kGy is sufficiently effective to give better safety levels of fungal contaminations. Hydrothermal treatments, fermentation, and germination are most effective in reducing the antinutrients of velvet seeds (Wanjekeche *et al.*, 2003). Various processing technology has been investigated onto velvet seeds aiming to reduce the toxins.

Accumulated data on velvet bean processing are listed in Table 7 nevertheless literature are scarcely found on an instant ingredient from velvet bean to be modernized based on such huge various processing studied. Indigenous processing often seen as the long successfully tested processing as the prior art for developing instant ingredient oriented for neural diseases already well known obtained from velvet seed products. Besides its prospective and challenging economical values, it is warrants investigation of technological touch to patch a new usage of velvet bean better in environmentally friendly ways.

Aqueous boiling is the best method for L-DOPA removal from velvet seeds (Bressani *et al.*, 2003) and the products developed by International Institute of Tropical Agriculture (IITA), Benin from L-DOPA free velvet beans in Nigeria is accepted by the society (Versteeg *et al.*, 1998). Various processing methods have been tried by investigators to reduce L-DOPA of velvet seeds. Most of the methods employed were based on the use of water, chemicals, and thermal treatments (Bressani, 2002; Diallo and Berhe, 2003; Gilbert, 2002). Dry treatments are the most effective in reducing L-DOPA in velvet seeds and preventing L-DOPA racemization under roasting (Siddhuraju *et al.*, 1996), grilling is considered a better technique than cooking (Dossa *et al.* 1998). Extreme heating is unfavorable nutritionally due to poor protein availability as well as protein digestibility (Kakade and Evans, 1965) although it removes haemagglutinins. Moisture in seeds plays an important role in the destruction of trypsin inhibitors (Liener and Kakade, 1980). Water imbibes into the kernels through soaking, germination, or hydrothermal processing activates enzymes among others is those which can destroy

antinutrients in cereal and legume; for instance, phytase which is also favorable when the metabolites of fermentation provide lactic acid (Sandberg, 2002). Meanwhile, fermentation with inoculums helps us with enzymes obtained from microbes to complement the endogenous activated enzymes in the kernels. The best removal of toxins especially those which are water-soluble such as cyanide can be done simply by soaking and removal of testa before boiling, and generally, cooking significantly eliminate HCN in seeds of *Mucuna utilis* (Ravindran and Ravindran, 1988).

Based on data of estimated water uses in Table 7 soaking treatment would depend on the water-beans ratios. The elimination of toxins would necessarily balance with nutritional retentions, in particular, those water-soluble nutrients. With the challenge of limited clean water in the arid areas where the most common locations of velvet bean growth, a high water-beans ratio make the processing unlikely compatible. Heating in reduced water-beans ratios would be more realistic options. Yet, technology such as microwave heating still expensive, and education about its dangers should be introduced for society. Such an idea would only work in the area with the available electrical supply.

Table 7. Processing of velvet beans

Processing Types	Principal Steps	Results	Minimum water (%v/b seeds)*	References
		Germination		
Germination	i) **Sterilized** (1% mercuri chloride), **rinsed**; **soaked** (distilled water, 4 °C, 12 h); **germinated** (24, 48, 72, 96, and 120 h 30 °C); **moistened** (distilled water 12 h), **rinsed the sprout** (distilled water)		**Total: 350** soaking: 100 moistening: 25 x 10 times=250 rinsing: 100	Gurumoorthi and Uma (2011)
	ii). **Sterilized** (ethanol soaking, 1 min), **soaked** (distilled water 1:10 w/v, 12 h, 25 °C), **drained**, **spread** (thick wet cotton wool), **germinated** (dark 3 d), **dehulled**, **frozen** (-21 °C 12 h) to stop germination, **dried** (oven 50 °C, 24 h), **ground** (≤500°m), **frozen** (-21 °C, 12 h)		**Total: 1,000** soaking: 1,000	Mugendi *et al.* 2010
	Room temperature, humidified cotton beds, 72 h		**Total: 100**	Balogun *et al.* (2017)
Germination to reduce trypsin inhibitor activity	Germinated (5 and 7 d)	Reduction of trypsin inhibitors up to 84.5 and 85.4%.	insufficient information	Wanjekeche *et al.* (2003)
Germination and boiled	**Germinated** (5 and 7 d), **boiled**	Reduced L-DOPA 38.5%	**Total 300%** soaking 100%, boiling: 200%	Wanjekeche *et al.* (2003)
Germination and malting *mucuna* seeds to reduce trypsin inhibitor activity	Germinated (2 vs. 6 d)	Decreased trypsin inhibitor activity 1.88 vs. 0.82 TUI/mg).	Total 300% soaking 100%, :daily weting 200%	Bressani *et al.* (2003)
Sprouting and oil frying (Lambadi Ethnic, India)	Mixed red soil paste (1:5 w/v) – beans ratios of 2:1; **humidified** with wet cloth, **incubated** for 7 d, 25 °C; sprout **separation**, **washed**, **dried** 85-90 °C, 15 min	Increased free phenolics by 4-11% (5,81-9,25% vs. 5.24-8.65%)	wetting: 100%; washing: 100%	Vadivel and Biesalski (2012)
		Fermentation		
Fermentation	*R.oligosporus* fermentation		Total 300% soaking 100%, boiling: 200%	Egounlety (2003)

Processing Types	Principal Steps	Results	Minimum water (%v/b seeds)*	References
	Bacillus sp. Fermentation		Total 300% soaking 100%, boiling: 200%	Egounlety (2003).
	R. oligosporus FNCC 6010, *R. oryzae* FNCC 6011, hybrid of they both 5 days fermentation,	*R. Oligosporus* reduced L-DOPA up to 90%		Balogun *et al.* (2017) Balogun *et al.* (2015)
		Soaking		
Mechanical and physical methods to reduce L-DOPA of *mucuna* seeds	(i) **cracked**, **soaked** in running water (from a faucet, 36 h)	Decreased L-DOPA up to 0.08%	continuous soaking: 75% x1.5 d =112.5%	Diallo and Berhe (2003)
	(ii) **dialyzed-like** whole seeds (cloth bag, **immersed** in a flowing river, 3 d).	Decreased L-DOPA up to 1.60%	immersion: 1,000%	Diallo and Berhe (2003)
	(iii) **leaching** of cracked seed (running water via faucet, 48 h)	Decreased L-DOPA 4.33%	leaching: 75%x2 d = 150%	Diallo and Berhe (2003)
	(iv) **leaching** of whole seeds (running water via faucet, 48 h)	Decreased L-DOPA 4.93%	leaching: 75%x2 d = 150%	Diallo and Berhe (2003)
Physicochemical methods to reduce L-DOPA and trypsin inhibitors of *mucuna* seeds.	Soaked (22 °C, 96.5 h)	70% retention of L-DOPA	Soaking: 100%	Bressani *et al.* (2003)
	Soaked (45 °C, 96.5 h)	Retention decreased to 51%	Soaking: 100%	Bressani *et al.* (2003)
	Soaked (66 °C, 96.5 h)	Retention decreased to 27%	soaking: 100%	Bressani *et al.* (2003)
Soaking and periodically changing water (60°C) toward white and mottled seeds of *mucuna*	Soaked, periodically water changed (60 °C, 48 h)	Reduction of L-DOPA up to 22-30%	Replenished soaking: 200%	Bressani *et al.* (2003)
Acidic soaking and heating	Acidic soaking and mild heating for 48 h		Soaking and heating: 150%	Mugendi (2010)
Soaking in tamarind solution and cooking	Tamarind solution at pH 2.75, **soaking** beans at ratio of 1:10 w/v, **stayed dark** (8 h, 25 °C), **rinsing**, **cooking** 1:10 w/v at 85-90 °C, 45 min (Kanikar tribe, Inda)		Soaking: 1,000% rinsing: 1,000%	Vadivel and Biesalski (2012)
Soaking	Soaked ($Ca(OH)_2$ solution)		Soaking: 100%	Vadivel and Biesalski (2012)
Soaking and cooking	Soaked (freshwater, 48 h), seed coat removal after 24 h, replacing water (12 h); cooked (water, 60-90 min)		soaking: 200% cooking: 100%	Diallo *et al.* (2002).
Soaking and cooking	Soaked (24 h), cooked (60 min)		Soaking: 200% cooking: 100%	Tuleun *et al.* (2009)
Soaking half mature *M. Capita* W. and A.	Peeled, soaked (water or salt solution, 2-3 d, every day water renewal)		Soaking: 100% x 3 d = 300%	Heyne (1987)
Soaking and frying to reduce HCN	Soaked (0.5% natrium bicarbonate, 12 h), fried Soaked (1.5% natrium bicarbonate, 12 h), fried	14.71 – 18.36 ppm	soaking: 100%	Sudiyono. (2010)
Soaking, antinutritional of *mucuna pruriens*.	Soaked (sodium carbonate solution)	Total free phenolics reduction (56%)	soaking: 100%	Vijayakumari *et al.* (1996)
	Soaked (distilled water)	Total free phenolics reduction (47%).	soaking: 100%	Vijayakumari *et al.* (1996)

Processing Types	Principal Steps	Results	Minimum water (%v/b seeds)*	References
Soaking to reduce phytic acid	Soaked (distilled water)	Decreased 27%	soaking: 100%	Sandberg (2002)
	Soaked (sodium bicarbonate)	Decreased 17%	soaking: 100%	Sandberg (2002)
Soaking and cooking to reduce phytic acid	Soaked, cooked (90 min)	Further reduced 18%	soaking and cooking: 150%	Sandberg (2002)
	Soaking, autoclaving (45 min)	Further reduced 44%	soaking and autoclaving: 150%	Sandberg (2002)
Soaking, autoclaving and cooking *mucuna* seeds in to remove phytic acid	Soaked (various solutions), autoclaved and cooked	Decline in phytate content (27-34% and 38-51%)	soaking and autoclaving: 150%	(Siddhuraju and Becker 2001).
Soaking and cooking to eliminate trypsin inhibitor	Soaked (water, 48 h), cooked (30 min)	Complete elimination	soaking and autoclaving: 150%	Udedibie and Carlini (1998)
		Boiling		
Boiling	Boiled up to 40 min		boiling: 100%	Osei-bonsu *et al.* (1996)
Boiling and dehulling to reduce L-DOPA (*m. Pruriens* var. *Utilis*) seeds	Boiled (45 min), dehulled	Decrease L-DOPA up to 6.36% (raw) to 4.71%	boiling: 100%	Egounlety (2003)
	Boiled (45 min), dehulled, soaked (12 h)	Reduced L-DOPA up to 6.36% (raw) to 2.29%	soaking and boiling: 200%	Egounlety (2003)
	Boiled (45 min), dehulled, soaked (12 h), re-soaked (12 h)	Reduced L-DOPA up to 6.36% (raw) to 1.36%	boiling, resoaking: 300%	Egounlety (2003)
	Boiled (45 min), dehulled, soaked (12 h), re-soaked (12 h), re-boiled (45 min)	Reduced L-DOPA up to 6.36% (raw) to 0.64%	boiling, resoaking: 400%	Egounlety (2003)
Boiling 'Magadi soda' (hydrated sodium carbonate) to reduce L-DOPA in whole mature seeds of *mucuna pruriens*	Boiled in alkaline solution	Reduced L-DOPA by 59.3% (5.75% vs. 2.34%),	boiling: 100%	Wanjekeche *et al.* (2003)
	Boiled in cob ash solution	Reduced by 58.1% (5.75 vs. 2.81%).	boiling: 100%	Wanjekeche *et al.* (2003)
Boiling	Boiled in citric acid solution	Reduced by 49.7% (5.75 vs. 2.89%).	boiling: 100%	Wanjekeche *et al.* (2003)
Boiling	Boiled in bean stover ash solution	Reduced by 47.4% (5.75 vs. 3.02%).	boiling: 100%	Wanjekeche *et al.* (2003)
Boiling	Boiled seeds in water	Reduced L-DOPA up to 24.9%	boiling: 100%	Wanjekeche *et al.* (2003)
Boiling of *mucuna cochinchinensis* to eliminate haemagglutinating activities.	Boiled (90 min, 100-105 ºC)	Failed to eliminate all	boiling: 100%	Ukachukwu and Obioha (2000)
Boiling to reduce trypsin inhibitor	Boiled in water	Reduced up to a greater extent 89.7% (27.18 vs. 2.80 TIU/mg).	boiling: 100%	Wanjekeche *et al.* (2003)

Processing Types	Principal Steps	Results	Minimum water (%v/b seeds)*	References
Boiling velvet bean	Soaked (plain water, 24 h, room temperature), washed, put into boiling water, boiled 20, 40, and 60 min),drained, sundried (4 d), ground	Selenium content (0.24 ppm vs. 0.09-0.12 ppm), iron (103 ppm vs. 70-90 ppm), and phosphorous (0.41% vs. 0.26-0.34%) among boiling time course there were relatively insignificant. Crude protein (29.37% dm vs. 27.93-28.27%), lipid (5.9% vs. 3.17-4.53%), and ash (4.43% vs. 6.68-8.78%). Reduced almost half essential amino acids due to the length of boiling time. HCN 33.46 mg/kg DM vs. 29.02-32.04 mg/kg), tannin (1.41 g/kg vs.0.99-1.16 g/kg), trypsin inhibitor activity (33.59 TUI/mg vs. 17.77-23.03 TUI/mg), and oxalates (1.95 g/kg dm vs. 1.38-1.90 g/kg).	soaking, washing, boiling: 300%	Tuleun *et al.* (2009)
		Others		
Pound and ground	Pounded, cracked, drained, hulled, ground		insufficient information	Osei-bonsu *et al.* (1996)
Microwave assisted heating	Microwave heated (130 ºC) overnight soaked, microwave heated (130 ºC)	Increased L-DOPA	soaking: 100%	Kala and Mohan (2012)
Dehulling/soaking and irradiating *mucuna* seeds	Dehulled, irradiated Soaked, irradiated	Reduced total phenolics (up to 80%)	soaking: 100%	Siddhuraju *et al.* (2000)
Gamma irradiation				Bhat *et al.* (2007)
Processing methods suitable for household and community level preparations to reduce L-DOPA of *mucuna* (raw white 3.75%), (raw speckled 3.90%), (raw black 4.36%), (pre-soaked speckled 4.02%)	Boiled (water)	Reduced L-DOPA up to 48.5% (4.02 vs. 2.07%)	boiling: 100%	Nyirenda *et al.* (2003)
	Boiled grits (water)	Reduced L-DOPA up to 57% (4.02 to 1.72%)	boiling: 100%	Nyirenda *et al.* (2003)
	Soaked grits (0.25% sodium bicarbonate (1.5 L), boiled (1.5 L), soaked (1.5 L, 24 h)	Extracted L-DOPA approximately 90% (4.02% vs. 0.39%).	boiling and resoaking: 3,000%	Nyirenda *et al.* (2003)
	Soaked (0.25% sodium bicarbonaten 1.5 L), boiled (1.5 L), soaked (1.5 L, 24 h)	Reduced L-DOPA up to 67%.	boiling and resoaking: 3,000%	Nyirenda *et al.* (2003)
	Soaked grits (24 h, 3 L water)	Reduced L-DOPA up to 54% (4.02 vs. 1.86%).	soaking: 3,000%	Nyirenda *et al.* (2003)
Various cooking treatments to reduce L-DOPA in *mucuna* seeds.	Microwave, vapor, in various water solutions at ph 3, 6, 7, and 11, cooking in alkaline sodium hydroxide/potassium hydroxide/calcium hydroxide	Not effective	soaking an cooking: 200%	Garcia-Echeverria and Bressani (2006)
	Cooked (calcium hydroxide, pH 9), washed in hot water	Reduction up to 80.4%	**total= 300%** cooking: 100% washing: 200%	Garcia-Echeverria and Bressani (2006)

Processing Types	Principal Steps	Results	Minimum water (%v/b seeds)*	References
Cooked yellow powder as soup thickener	Cracked (hitting with a hard object), cooked, hulled, ground, mixed with red palm oil		cooking: 100%	Ezueh (1997)
Cooking and autoclaving to reduce hemagglutinating activity		Reduced hemagglutinating activity up to 89-99%	cooking and autoclaving: 150%	Vijayakumari *et al.* (1996).
Cooking to eliminate haemagglutinin activity oin *M. cochinchinensis* seeds	Cooked (3 h, 100 °C)	Eliminated haemagglutinin activity	cooking: 100%	Onwuka (1997).
Cooking to inactivate trypsin inhibitors in *mucuna* seeds	Cooked (1 h, 96 °C)	Completely eliminated	cooking: 100%	Udedibie and Carlini (1998)
Cooking to decrease antitryptic activity		Totally eliminated	cooking: 100%	Ravindran and Ravindran (1988).
Cooking to reduce cyanide, in mucuna	Cooked	Reduces cyanide up to 46%	cooking: 100%	Montgomery (1980)
Toasted flour	Toasted (5-10 min), ground		sanitary need: 25%	Sridhar and Bhat (2007)
Toasting to eliminate trypsin inhibitors of *M. Utilis* (raw, 2,170 TIU/g)		Elimination of 42% (6,979 vs. 11,865 TIU/g).	sanitary need: 25%	Ravindran and Ravindran (1988)
Roasting	Roasted (100 ºC)	Increased L-DOPA	sanitary need: 25%	Mugendi and Njagi (2010)
Roasting of *mucuna* seeds to reduce trypsin inhibitor activity	Roasted (30 min)	Reduced the trypsin inhibitors (raw 18.90 vs. 1.58 TUI/mg).	sanitary need: 25%	Bressani *et al.* (2003)
Roasting and dehulling to reduce cyanide, (raw 18.6 mg/kg)	Roasted Dehulled, roasted	Complete removal of HCN	sanitary need: 25%	Agbede and Aletor (2005)
Dry heat treatment and autoclaving *M. pruriens* to reduce phytic acid	Dry heated, autoclaved	Reduced the phytic acid (36% and 47%)	**total: 75%** sanitary need: 25% autoclaving: 50%	Siddhuraju *et al.* (1996)
Dry heat treatment to reduce hydrogen cyanide (HCN) *M. Pruriens* seeds	Dry heated	Reduced HCN (67%)	sanitary need: 25%	Siddhuraju *et al.* (1996)
Autoclaving to reduce hydrogen cyanide (HCN) *M. pruriens* seeds	Autoclaved	Reduced HCN (68%)	autoclaving: 100%	Siddhuraju *et al.* (1996)
Autoclaving to reduce cyanide	Autoclaved	Reduces cyanide up to 75%.	autoclaving: 100%	Montgomery (1980).
Autoclaving antinutritional of *M. pruriens* to reduce tannins	Autoclaved (45 min)	Reduced tannins (71%).	autoclaving: 100%	Vijayakumari *et al.* (1996)
Autoclaving, dehulling and roasting, dehulling and soaking	Autoclaved (raw/ dehulled), Dehulled, roasted Dehulled, soaked (urea)	Completely removed trypsin inhibition activity (raw 25.3 mg/g)	autoclaving: 100% autoclaving and soaking: 150%	Agbede and Aletor (2005)
Dehulling and cooking/roasting to reduced lectin *M. pruriens* seed flours.	Dehulled, cooked Dehulled, roasted	Completely eliminated lectin (raw 4.0 HU/mg).	cooking: 100%	Agbede and Aletor (2005)
Dehulling and roasting to reduced phytin and phytin phosphorus *mucuna* seeds (raw 15.3 and 4.3 mg/100 g)	Dehulled, roasted seed flours	Reduced phytin and phytin phosphorus (6.0 mg/100 g).	sanitary need: 25%	Agbede and Aletor (2005)

Processing Types	Principal Steps	Results	Minimum water (%v/b seeds)*	References
"Gedebel benguk" making	Boiled completely cooked, removed peel, placed into a bamboo basket for 'dialyzing like' process using the flowing clean water, chopped finely, steamed, mashed, put into a mould and placed onto banana leaves, covered with particular bamboo leaves for spontaneous fermentation (uncovered area mixed with Rhizopus sp. fermentation).	no data on chemical effects	**total: 650%** boiling: 100% dializing-like: 500% steaming: 50%	Heyne (1987)
"Dage benguk" making	Steamed completely cooked, removed peel, soaked (water, 48 h), placed into a small basket (covered with banana leaves, 3-4 d), re-steamed	no data on chemical effects	**total= 300%** steaming: 50% cooking: 100% soaking: 100% resteaming: 50%	Heyne (1987)
Steaming and foaming	Steamed (lipidic foam)	Safe (tasty)	steaming: 50%	Heyne (1987)

In Indonesia, mucuna seeds were consumed depends on the variety. *M. hirsuta* W. and A. indicate the needs of a lot of water to make the seed edible: (a) the young seed is boiled, peeled, and washed thoroughly with fresh water and then steamed; (b) mature seed is broken to separate the seed from the peel and the kernel can be eaten directly (*M. hirsuta* W. and A.) or the mature seed is boiled, its peel is removed, soaked into water for 24 h with water is renewed every 8-12 h. Any processing should involve water to soak up to 48 h. Generally, old documents have recorded that soaking is the key processing to avoid a headache from improper removal of velvet bean components during processing (Heyne, 1987).

Antioxidant capacity measured by DPPH methods for the velvet bean flour obtained from germination is superior compared to Rhizopus spp FNCC 610 and 6011 fermentation, as well their hybrid (Balogun *et al.*, 2017). Meanwhile, *Rhizopus oligosporus* has acted well-reducing L-DOPA in the velvet bean after 5 days fermentation (Balogun *et al.*, 2015) which reached 90%. In this case, the seed coat of black velvet bean does not only contribute more scavengers (Balogun *et al.*, 2017) but also becomes important provision to supply mineral intakes (iron 7.9 mg/100 g dry weights, and other minerals comparable to those of soybean) (Mugendi *et al.*, 2010a) and dietary fibers for human as well. L-DOPA is concluded existing in the seed coat higher (6.98%) in the unhulled raw velvet beans than dehulled one (5.71%) (Mugendi *et al.*, 2010b). Therefore, it is recommended to involve the seed coat of the velvet bean in commercial production of health ingredients from the bean.

Then, germination is outnumbered other methods for other choices. It resulted in mild eradication of antinutrients, phenolics, and L-DOPA (6.77-43.78%). Indeed, there are several processes capable of eliminating L-DOPA or antinutrients at the safe levels recommended by WHO/FAO (≤0.1%) (Mugendi *et al.*, 2010b). Concerning priority of the Parkinson disease prevention and long term preventive-curative uses, the health ingredients expected to be produced is flour containing sufficient levels of L-DOPA i.e. 4-6% or 30 g mucuna seed powder (Katzenschlager *et al.*, 2004) Because L-DOPA is thermally resistant (Mugendi *et al.*, 2010b), to decreasing other antinutrient factors (i.e. the well-known L-DOPA, total free phenolics, tannins, haemagglutinin, trypsin and chymotrypsin inhibitors, antivitamins, protease inhibitors, phytic acid, flatulence factors, saponins, and hydrogen cyanide) more after germinating, it is easier to treating further by any types of food processing. Nevertheless, it is not recommended to have a monotonous diet based on velvet bean food products because histological examination indicates inflamed liver and kidney even though the L-DOPA has reached safety levels (Mugendi *et al.*, 2010a). A study using velvet bean as part of chicken feeds (Tuleun *et al.*, 2009) show changes due to boiling resulted in broiler

biochemistry effects of higher weight gain (26.32 g/d vs. 34.68-39.79 g/d), protein intake (16.79 g/d vs. 17.50-18.93 g/d) and PER (1.55 vs. 1.99-2.10). Soaking the beans for 24 h and cooking for 60 min is recommended as adequate to improve the nutritional quality of velvet beans. In an attempt to reduce water uses, germination and fermentation are the best to simultaneously change several anti-nutritional factors. To make it standardized processing then the use of the controlled instrument is important therefore the temperature and humidity are at the right levels to make sure biochemical changes consistently.

LOWER WATERED PROCESSING ALTERNATIVES

Malting technology for preparing malt in beer making is the most established technology of seedling. Germination was adopted from malting technology (Dabija 2012): velvet beans were soaked in 1:2 ratios of beans: water for 4-6 h until moisture content of 30%; sprayed wet for 16 h until moisture content (using infrared moisture tester) MC 31-32%; soaked for 2-4 h until 38% MC; sprayed wet for 14-18 h to reach 40%. Then the beans entered germination step at humidity levels of 75% and 85%, temperature 15 °C and 20 °C steeping until it started to be rootlets. At this stage, cold water was introduced to reduce the temperature and MC content increased to 50-52%. Total water estimated in malting technology is presented in Figure 2 (written in bold letters) and the total water requirement is 370%. In wheat milling technology, to moisten grains before commencing grinding/milling is important and at this stage variations of kernel characteristics become crucial.

Another alternative is steaming of velvet bean: to soak velvet bean at MC of 40% was steamed at 80 °C for 20 min, 30 min, and 45 min which was placed making bed beans against the steam flow. Steaming has limited water supply for gelatinization therefore L-DOPA leaching will be controlled. The effect of processing and water needs is listed in Table 8.

It has not been available research on instant food ingredients aiming to service Parkinson's disease sufferers. Meanwhile, relationship between L-DOPA and germination time course is expressed as $Y = 0.175 + 2.057\ X - 1.548\ X^2$ (R^2=0.791) (Gurumoorthi *et al*., 2011). From Table 8 the priority is that L-DOPA removal is controlled to the optimal levels for dietary L-DOPA at safe levels. The second priority is antitrypsin and cyanides compulsorily reach maximum reduction. Thus alternatives mucuna processing is combinations of aquadest soaking, germination, boiling, cooking especially those involving oils and foaming (Heyne, 1987), roasting, oil frying (Sudiyono, 2010). To achieve the goal of instant ingredients thus foaming and steaming must be involved during processing. Possible products developed are suggested in the present paper include mayonnaise, ice cream, marshmallow, meringue filler, oil soups, or foamed dried flour.

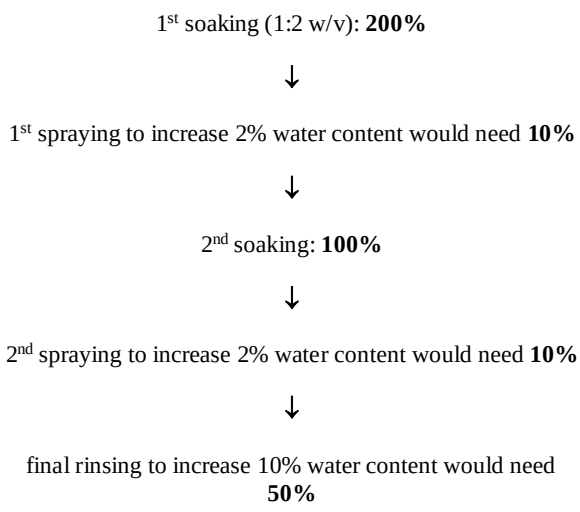

Figure 2. Estimation of malting technology of wheat

Table 8. Processing effects on mucuna seeds components and water needs during processing

No.	Processing	Components	Reduction (%)	Water (%)
1.	Soaking-germination	Antitrypsin	85.4	350
2.	Germination-malting	Antitrypsin	43.62	370
3.	Water boiling	Antitrypsin	89.7	100
4.	Soaking-cooking	Antitrypsin	100	150
5.	Cooking	Antitrypsin	100	100
6.	Cooking	Antitrypsin	100	100
7.	Toasting	Antitrypsin	42	0
8.	Roasting	Antitrypsin	8.36	0
9.	Autoclaving (raw/dehulled)	Antitrypsin	100	50
10.	Dehulling-roasting	Antitrypsin	100	0
11.	Dehulling-urea soaking	Antitrypsin	100	100
10.	Fermentation	L-DOPA	90	100
12.	Cracking-continuous soaking (in the river)	L-DOPA	0.08	unlimited
13.	Dialyzed-like	L-DOPA	1.6	500
14.	Cracking-continuous leaching	L-DOPA	4.33	112.5
15.	Leaching	L-DOPA	4.93	1,000
16.	Soaking 22 ºC	L-DOPA	30	150
17.	Soaking 45 ºC	L-DOPA	49	100
18.	Soaking 66 ºC	L-DOPA	73	100
19.	Soaking, changing water 60 ºC	L-DOPA	30	200
20.	Soaking-germination-boiling	L-DOPA	38.5	1,000
21.	Boiling-dehulling	L-DOPA	24	100
22.	Boiling-dehulling-soaking	L-DOPA	64	200
23.	Boiling-dehulling-resoaking	L-DOPA	79	300
24.	Boiling-dehulling-resoaking-reboiling	L-DOPA	90	400
25.	Alkaline boiling	L-DOPA	59.3	100
26.	Cob ash boiling	L-DOPA	58.1	100
27.	Citric acid boiling	L-DOPA	49.7	100
28.	Bean stover ash boiling	L-DOPA	47.4	100
29.	Water boiling	L-DOPA	24.9	100
30.	Water boiling	L-DOPA	48.5	100
31.	Water boiling-grits	L-DOPA	57	100
32.	Na(bicarbonate) soaking-grits-boiling-resoaking	L-DOPA	90	3,000
33.	Na(bicarbonate) soaking-boiling-resoaking	L-DOPA	67	3,000
34.	Water soaking-grits	L-DOPA	54	3,000
35.	Ca(hydroxide, ph 9) cooking, hot water washing	L-DOPA	80.4	300
36.	Soaking-Na(carbonate)	Total phenol	56	150
37.	Soaking-aquadest	Total phenol	47	100
38.	Dehulling/soaking-irradiating	Total phenol	80	100
39.	Soaking-aquadest	Phytic acid	27	200
40.	Soaking-Na(carbonate)	Phytic acid	17	150
41.	Soaking-cooking	Phytic acid	18	150
42.	Soaking-autoclaving	Phytic acid	44	150

No.	Processing	Components	Reduction (%)	Water (%)
43.	Soaking-autoclaving-cooking	Phytic acid	51	150
44.	Dry heating	Phytic acid	36	0
45.	Autoclaving	Phytic acid	47	50
46.	Dehulling-roasting	Phytic substances	70.4	0
47.	Autoclaving	Hemagglutinating activity	99	50
48.	Cooking	Hemagglutinating activity	89	100
49.	Cooking	Hemagglutinating activity	100	100
50.	Cooking	Cynide	46	100
51.	Roasting	Cynide	100	0
52.	Roasting-dehulling	Cynide	100	0
53.	Dry heating	Cynide	67	0
54.	Autoclaving	Cynide	68	50
55.	Autoclaving	Cynide	75	50
56.	Dehulling-cooking	Leptin	100	100
57.	Dehulling-roasting	Leptin	100	0
58.	Soaking-washing-boiling-draining-drying	Micronutrients	50	300
59.	Autoclaving	Tannin	71	50

PHYSICOCHEMICAL PROPERTIES OF VELVET BEAN FLOUR FROM VARIOUS PROCESSING

Data in Table 9 indicate the effects of the cooking of various techniques. Dehulling increased water absorption capacity as well as oil absorption capacity, foam stability, and viscosity but it reduced gel, emulsion, and foaming capacity, swelling power, bulk density, and pH (Balogun and Olatidoye, 2012). Defatting treatment on various mucuna members indicated increasing water absorption capacity and foam capacity but reducing emulsion capacity (Adebowale *et al.*, 2005). Heating increased water and oil absorption capacity but reduced emulsion and foaming capacity whereas foam stability are relatively similar (Ahenkora *et al.*, 1999). Acetylating of velvet bean flour showed an increase in water and oil absorption capacity while oxidizing only increased solubility of the flour quite profoundly (Adebowale and Lawal, 2003).

Irradiation can be considered to preserve almost all physicochemical properties with better cooking time. Irradiation reduces the texture of raw velvet beans at dosages >7.5 kGy might be due to polymer degradations, solubility, turgor, and moisture losses (Bhat *et al.*, 2007). Irradiation gives better sterilization on microbial contamination on the seed surfaces (Bhat *et al.*, 2007) using ionized irradiation and electron beam irradiation. These technologies are expensive and several important properties similar to those of whole velvet bean in the study of Balogun and Olatidoye (2012). Shorter cooking time after irradiation treatments may reduce energy for cooking but it is unclear if the water requirements for cooking would also be reduced. The availability of lipid/oil in velvet bean food preparation that is considered safe (Vadivel and Bielsaski, 2012) gives clues that defatting is unnecessarily carried out. Lipid is required to 'tame' itching component and to make better palatability (Heyne, 1987). Chemical modification through acetylating and oxidizing may be useful to improve the solubility of velvet bean products during processing. However, washing steps after treating the beans with the chemicals would consume a lot of water. The left problem using the whole bean is more likely to get a long time cooking due to the whole beans to have a high bulk density (Seena and Sridhar, 2005). Therefore, it is noteworthy to keep

Table 9. Physicochemical properties

Physicochem. properties	Balogun and Olatidoye (2012)		Adebowale *et al.* (2005)		Ahenkora *et al.* (1999)		Adebowale and Lawal (2003)			Bhat *et al.* (2008)	
species	*Mucuna utilis*,		*M.cochinchinensis, M. deerigeana, M. pruriens, M. rajada, M. veracruz* (mottle) and *M. veracruz* (white)							*Mucuna pruriens*	
	whole	dehulled	full fat	defatted	raw	heated	native	acetylation	oxidized	raw	irradiated (2.5-30 kGy)
WAC	2.05	2.45	1.40-2.20	higher	140%	156%	1.71	121		ca. 2.2 mL/g	slightly increased
OAC	1.19	1.45			76%	86%		increased	reduced	ca. 1.5 mL/g	slightly increased
GC (%)	4.12	3.85	14-20								
EC	24.42	22.40	78-90%	56-68%	60%	50%				ca. 50%	relatively similar
ES										ca. 90%	slightly increased
SP	2.68	2.28					2.7-13.3	3.6-15.6	2.3-9.9		
FC (%)	21.52*	16.60*	9.6-19.23%	50-84.30%	53%	4%				ca. 39%	slightly increased
FS	21.00^{30min} 18.00^{60min}	26.00^{30min} 21.00^{60min}			10%	9%				ca. 60%	relatively similar
viscosity (Ns/m^2)	17.52	22.18									
ρbulk (g/cm^3)	1.25	0.94								0.649±0.05	0.649±0.05
pH	6.72	6.51									
pI			4-5		4.5						
solubility (g/g)							21-143	36-147	52-200		reduced
t_{min} cooking (min)										22	14-21
WUR										1.43±0.002	1.45-1.56
elongation ratio										1.26±0.08	1.23-1.4
GSL (%)										20.43±0.006	12.13-20.10
-L/B ratio										1.62±0.21	1.59-1.62

* in mL, WAC: Water absorption capacity, OAC: oil absorption capacity, GSL: Gruel solid loss, GC: gelation capacity, FC: foaming capacity; FS: foaming stability, EC: emulsion capacity, ES: emulsion stability, SP: swelling power, WUR: water uptake ratio

a balance between low water consumption while processing the velvet bean also saving energy.

POTENTIAL COMMERCIALIZATION OF VARIOUS PROCESSING

Commercial velvet bean powder has been available to cure Parkinson's disease. This is under the protection of US Patent No. 7470441B2 and US7470441B2, WO2017126959A1, and EP1567177A2. The most commercialization of velvet bean use is in the form of a medicine regime. As far as it is concerned, the patent or other intellectual properties of instant velvet bean flour as a food ingredient to be raw materials of functional foods is not found. Another commercialization potential is the use of the flour as protein-lipid rich food ingredients for daily menu components. A holistic value chain from agriculture to end-users of velvet bean flour also considered as environmentally friendly food chain because the mucuna plant is excellent green manure, controlling weed in the soil through its allelochemicals, DOPA; capable of nitrogen fixation in the soil, a good protein-lipid balance provision comparative to soybean, and can optimally support food sovereignty by optimal use of unfertile soils.

The patent No. 7470441B2 is about an extraction method for *M. pruriens* seeds to produce fractions or crude extract that contain at least one of active compounds, substance, ot their mixtures for pharmaceutical uses capable of preventing, reducing, and curing Parkinson's disease. The successive method uses solvents comprised of hexane, acetone, water-ethanol which contains vitamin C at particular levels. Pharmaceutically, the extract gives broader therapy including L-DOPA therapy, slowing down the development of the disease even though it onsets earlier yet the development can be retarded as well as to prevent or eliminate acute and chronic L-DOPA toxicity.

Patent application No. WO2017126959A1 is about food products containing fermented starch from diverse starch resources with claims of fermented starch content at 15% and inoculum levels of 0.1-10% providing health benefits and the food products are organoleptically well-liked by consumers. The claim covers up the processing methods for commercial productions i.e. the uses of particular moisture content, heating, cooling for appropriate fermentative temperature, inoculation for the claimed method.

Patent application No. EP1567177A2 is pointing out *M. pruriens* for neuroligical disease treatments focusing on pharmaceutical compositions that containing *M. pruriens* seeds or one or more of its components, substances, fractions, as well as their mixtures to prevent, remove or to treat the diseases. The claims also include methods to prepare them from *M. pruriens* for the aforementioned goals. The uses of this product include a wider spectrum of Parkinson's disease from retarding the need to give combination treatments initial onset, and the time course of L-DOPA effication as well as to prevent or to eliminate acute or chronic L-DOPA treatments. The focused components are bipolar-lipophilic fraction compounds either in the form of an infusion, injection solutions, gelatin capsule, tablets, and slow-released tablets. The targeted compounds under the claims have neurostimulator and neuroprotective functions obtained from particular *M. pruriens* (M-PL0100, M-EL100, M-BL0100, LAT543-0 dan M-W-EL1299, M-W0100, MWEL0700, M-ML0100). The scope of pharmaceutical preparation composition is (1) to inhibit L-DOPA metabolism or dopamine, (b) to improve L-DOPA absorption to generate initial L-DOPA effication and (c) to lengthen L-DOPA effication. Patent No. US7470441B2 claims extraction method of *M. pruriens* seeds using hexane, the mixture of water and ethanol containing 0.5% vitamin C for pharmaceutical goals.

Such pharmaceutical preparations can have environmental risks because of organic solvent waste. Moreover, the area where velvet beans produced is categorized by a fragile environment in sustainable viewpoints, which warrant another processing method that more environmentally friendly. Clean water is an obstacle in this area to make the velvet beans safe from high levels of L-DOPA and cyanides. To be positive towards green manure contributions of velvet bean planting, thus the commercialization model is important to be integrated commercialization system.

Commercialization at small-medium scale enterprises producing foods or food ingredients is considered as more realistic. Therefore, food processing oriented for health ingredients is important. Such food processing technology with less water consumption is investigated to achieve a system of food commercialization for velvet beans and oriented to get health-related food materials. It is expected that less water consumption processing would give better economic feasibility.

CONCLUSION

Velvet bean uses for health-related food product development warrant research on a more holistic approach to achieving sustainable commercialization in a way that environmentally friendly, by reducing the use of organic solvents, less water consumption during processing, while during its farming the mucuna plant could give healthier soils. Consequently, the healthier the soils, the better the agricultural productions and finally, and hopefully, society gets benefits for their well being and welfares.

Based on this literature reviews it is concluded that steaming might the best compromising of functional food ingredients where low water consumption, safe and effective energy uses because of the power of steam and latent energy involved. The expectation is capable of producing safe functional food ingredients for diabetes mellitus and/or Parkinson by the use of L-DOPA, cyclic-D-chiro inositol, and fibers also of the basic nutrients. The protein content of velvet bean comparable to that of soybean yet growth values (protein effective ratio) is poor so monotonous diet based velvet beans is not recommended. As functional ingredient, it can be managed to reach safe dosages in daily intakes. However, all hypotheses were currently being proven in our research group. Using steaming and germinating to characterizing steamed-whole flour velvet beans.

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