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EFFECT OF GERMINATION, ALKALINE AND ACID SOAKING AND BOILING ON THE NUTRITIONAL VALUE OF MATURE AND IMMATURE *MUCUNA* (*Mucuna pruriens*) BEANS

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SUMMARY

Mucuna is one of the green manure/cover crops introduced in Kenya as an alternative means of improving soil fertility. Despite the proven high potential to increase soil fertility, adoption by farmers is not certain unless multiple uses are identified. In order to enhance the food potential of *Mucuna*, a study was carried out to determine the effect of cooking immature and mature beans in water or locally available alkaline or acid medium and the effect of germination on the cooking time, nutritional composition and anti-nutritional factors. Cooking time for mature beans was reduced from 4.5 h for beans boiled in water to 1.4 h for beans boiled in Magadi soda, 1.2 h for maize cob ash, 1.8 h for bean stover ash and 2.5 h for citric acid. Boiling whole mature beans in Magadi solution reduced L-Dopa by 59.3% while boiling in maize cob ash, citric acid and bean stover ash solution reduced it by 58.1, 49.7 and 47.4%, respectively. Particle size reduction led to higher extraction of L-Dopa. Boiling in water or germination for 5 d combined with boiling reduced the L-Dopa by only 24.9 and 38.5% respectively. All the processing treatments tested significantly affected the proximate composition of the beans. When compared to raw beans, boiling in plain water caused higher increases in the protein content of both immature and mature beans than the other treatments. The alkaline treatments reduced the fibre and ash contents more than cooking in plain water. All treatments increased the carbohydrate content of the beans. Sensory evaluation revealed that while *Mucuna* beans cooked in alkaline additive were more palatable in taste and texture, beans cooked in acid were lighter in colour and more acceptable. Overall, the common beans were more palatable than *Mucuna*. Further product development research incorporating *Mucuna* processed beans into local dishes needs to be carried out to improve consumer acceptability.

Key words: *Mucuna*, cooking, composition, L-Dopa, anti-nutritional factors, germination.

INTRODUCTION

One of the major factors contributing to decreased food production in Kenya is low soil fertility. The situation is especially bad for poor small-holder farmers who cannot afford inorganic fertilizers to replenish soil nutrients. The need to identify alternative means of improving soil fertility has generated interest in green manure/cover crops.

Over the last five years, a variety of green manure legumes have been introduced into the farming systems of several communities in Kenya by the Legume Research Network Project and other research organizations. Among these legumes, *Mucuna* (*Mucuna pruriens*) has shown the greatest potential to improve soil fertility (Mureithi *et al*., 2000). Despite this high potential, wider adoption of *Mucuna* is not certain unless farmers can use it for other purposes that contribute to family welfare, either as food, animal feed or cash. Experiences with green manure legumes by researchers in the Legume Research Network project and the Resource Oriented Development initiatives project (RODI, 2000) show that farmers were reluctant to plant *Mucuna* and jackbean because they could not utilize the seeds as food, but they were more likely to plant other legumes like *Dolichos lalab* that were edible.

Although *Mucuna* bean has been utilized as food in many countries where it has been introduced for green manuring purposes (Versteeg *et al*., 1998), in Kenya, it has only been used as a beverage or 'cocoa' by farmers in the Coastal region and in parts of the North Rift region. The dry beans are roasted and ground to a fine powder (Saha and Muli, 2000). Farmers are not aware of other methods of utilizing *Mucuna* despite high bean yields (1-2 tons ha^{-1}). Literature indicates that the nutritional value of *Mucuna* bean compares closely with that of the common bean and other legumes (Bressani, 2002; Siddhuraju *et al*., 1996; Laurena *et al*., 1991). It can therefore contribute additional protein for many communities in Kenya which rely on starch-based diets and lack adequate protein in their diets. Protein malnutrition has been reported to affect about a third of the population in Kenya (GOK, 1994).

Mucuna bean contains several anti-nutritional factors, which have to be reduced to safe levels before it can be used as human food. The anti-nutrient of greatest concern is 3,4 Dihydroxy-L-phenylalanine (L-Dopa), which has toxic effects to humans if consumed in large amounts (Bressani, 2002). Several processing methods have been tried by researchers in various countries to reduce L-Dopa in *Mucuna*. Most of these studies have quantified the impact of typically water- and heat-based processing methods on the content of L-Dopa and other anti-nutrients. These methods require long soaking and cooking time (8 to 9 h), with frequent changes of water in order to reduce L-Dopa to safe levels (Bressani, 2002; Gilbert, 2002). Prolonged cooking may rid *Mucuna* of its beneficial nutrients, resulting in a product that is not very different from the typical starchy staples. It is also expensive in terms of fuel. In addition, today's consumers prefer easy-to-prepare foods due to the changing lifestyles.

In order to encourage farmers to utilize *Mucuna* as food and hence adopt it for soil fertility improvement, this project was carried out with the aim of identifying suitable processing methods for both mature and immature beans which would be rapid, would effectively reduce L-Dopa and other anti-nutritional factors, and would enhance the nutritional value and eating quality. Therefore, the objective of this study was to investigate the effects of cooking mature and immature *Mucuna* beans in water, alkaline or acid media, and to determine the effects of germination combined with boiling on cooking time, on the proximate composition, and on the content of L-Dopa and other anti-nutritional factors. An additional objective concerned establishing consumer acceptability of *Mucuna* processed by the above mentioned methods.

MATERIALS AND METHODS

Mucuna cultivation

Cream- and mottled-colored *Mucuna* (*Mucuna pruriens*) beans commonly grown in Kenya were used for the study. Seed was supplied by the Legume Research Network Project and sown at the onset of the long rains (1st week of April 2001) at the National Agricultural Research Centre, Kitale, Kenya. The soils are acidic with the pH ranging from 5.0 to 6.0. The area receives moderate annual rainfall averaging 1000-1200 mm. The seed was planted at a spacing of 90 x 60 cm with no fertilizer applied. Trellising was done to increase seed production. Pods containing immature seed were harvested in December 2001 (which corresponded to 10 weeks after pod formation). The seeds were removed from the pods by hand before processing or analysis. Mature seed was harvested in February 2002 and the seeds were manually removed from the dry pods.

Preparation of alkaline and acid additives

Locally available alkaline and acid materials were used to process *Mucuna* beans. The alkaline materials were 'Magadi soda' (or t*rona*, a hydrated sodium carbonate) obtained from Lake Magadi in Kenya, maize cob ash solution and bean stover ash solution. The acid material used was citric acid. All additives used in the study are commonly used in Kenya as cooking aids and serve the purpose of enhancing flavor and tenderizing food, hence reducing cooking time. Citric acid is mainly used as a flavoring agent.

To prepare solutions of 0.50 and 0.25% Magadi soda, 2 g and 1 g, respectively, was dissolved in 400 mL of distilled water. This procedure was also repeated for citric acid. Bean stover ash and maize cob ash solutions were prepared following the traditional method used by farmers. One hundred grams of ash were sieved and put in a plastic container with holes of diameter 0.5 cm at the bottom. The ash was pressed down slightly to form a filtering bed. Distilled water (500 mL) was added slowly making sure that the ash layer was not disturbed. The filtrate, amounting to about 350 mL, was collected in a beaker. One hundred milliliters of the filtrate were diluted to 400 mL with distilled water to make a solution of 1:3 dilution.

Effect of soaking medium and soaking time on the cooking time of mature *Mucuna* beans

One hundred grams of mature beans were soaked for 0, 12, 24 48, and 96 h in 400mL of either plain water, 0.25% Magadi solution or 0.25% citric acid at room temperature (19-20^{0}C). At the end of soaking, the soaking water was discarded and the seeds were boiled in 400 mL plain distilled water until cooked. The cooking time was determined from the time the water started boiling to the time the beans attained a soft texture and were easily mashed between the fingers.

Effect of alkalinity and acidity on cooking time, proximate composition and anti-nutritional factors of immature and mature *Mucuna* beans

Two hundred grams of mature beans were soaked in 400 mL of plain water for 48 h at room temperature and the water was discarded after soaking. Only grains that had absorbed water and were swollen were selected for further processing. One hundred grams of the swollen beans were weighed and the individual beans were chopped into 3 pieces of about 3-mm size to increase the surface area. Another sample of the beans (100 g) was left whole. The mature and immature beans were then boiled in 400 mL of 0.5%

Magadi solution, bean stover or maize cob ash solutions for 30 minutes. The cooking water including the seed coats was discarded. The bean sample was then washed in 500 mL of water while rubbing the seed in between the fingers to remove all the seed coats from the cotyledons (seed coats had become soft due to the effect of the alkaline). The seeds were washed again 3 times to remove all the seed coats. The cotyledons were then further boiled in 400 mL water for another 30 minutes, the water discarded, 400mL of water added again and the seed boiled again until the seed was soft.

The procedure was repeated with citric acid except that washing and removal of the seed coats was done after 1 hour of boiling because the seed coats were not as easily softened as in alkaline media. One additional treatment consisted of boiling the soaked seed for 30 minutes in 0.5% Magadi solution, then washing the seed to remove the seed coats followed by boiling in 0.5% citric acid. Immature green seed was also cooked in alkaline or acid following the above procedure but without prior soaking. The cooked seed was then dried in a forced air oven at 60^{o}C for 24 h and packed in sealed polythene tubes until chemical analysis was performed.

Effect of germination combined with boiling on the proximate composition and anti-nutritional factors of mature *Mucuna* seed

Two hundred grams of mature *Mucuna* beans were placed in a flat plastic dish and germinated for 5 or 7 d with enough water to cover the surface of the grain. The water was changed daily to avoid fermentation. At the end of each germination period, the bean sample was divided into two lots, one of which was dehulled while the other was not dehulled. Dehulling was done by rubbing the beans between the fingers and then washing to remove the seed coats. Each of these two lots was further divided into 2 additional lots, one of which was boiled in water for 1.5 h while the other was not boiled. The treatments for both 5- and 7-day germination were therefore as follows:

(i) No dehulling + no boiling

(ii) No dehulling + boiling for 1.5 h

(iii) Dehulling + no boiling

(iv) Dehulling + boiling for 1.5 h

The bean samples were dried for 24 h at 60^{o}C and sealed in polythene bags until analysis.

Consumer acceptability of *Mucuna* processed in alkaline and acid media

Farmers from Trans-Nzoia district of Kenya participated in evaluating the taste, colour and texture of *Mucuna* seed cooked in 0.5% Magadi soda, maize cob ash solution (1:4 dilution) and 0.5% citric acid. These were compared with the common bean. The farmers indicated their degree of acceptability for the different characteristics according to a 4-point hedonic scale (1=Like very much, 2=Like slightly, 3=Dislike slightly, 4=Dislike very much).

Sample analysis

Samples were taken from the processed and unprocessed beans and analyzed for proximate composition, content of L-Dopa, trypsin inhibitors and total tannins. Determination of moisture, crude protein, ether extract (crude fat), total ash, crude fibre and carbohydrates was done following standard methods of the AOAC (1984). The micro Kjeldahl method for crude protein and the Soxhlet extraction method for ether extract were followed. Trypsin inhibitors were determined following the method by Kakade *et al*. (1974), while the total tannin content was determined following the method of Hoff and Singleton (1977).

Analysis of L-Dopa

Analysis of the L-Dopa content in both mature and immature *Mucuna* beans was done following the procedure outlined by Myhrman (2002) using HPLC with UV detection at 279 nm. The column used was Zorbax Stable Bond SB-C18, 4.6 x 150 mm, 3.5 micron. Two mobile phases were used. Mobile phase A consisted of 0.1 M phosphoric acid, 1 mM 1-octanesulfuric acid (Sigma 0-8380), 2 mM disodium EDTA, adjusted to pH 3.0 with NaOH prior to final dilution with water of 18 megohm restistivity. Mobile phase B consisted of HPLC grade methanol. Elution was done using 90% A, 10% B at 1.0 mL min^{-1} for 15-20 minutes. Injection volume was 40 micro litres. Quantification of L-Dopa was based on a standard curve developed using 1.00 mM L-Dopa (Sigma D-9628), dissolved in water.

RESULTS AND DISCUSSION

Effect of soaking in water, alkaline and acid medium on the cooking time of mature *Mucuna* seed

Figure 1 shows the effect of soaking mature *Mucuna* bean in water and in mild alkaline and mild acid media on the cooking time. Soaking in water for 12 h only slightly reduced the cooking time (from over 6 h for the un-soaked beans to 5.5 h), indicating that the time was not sufficient. When the soaking time was increased to 48h, the cooking time reduced to 2.6 h, but when increased to 96 h, the cooking time increased to 3.9 h. This trend was also observed when the soaking medium was either alkaline or acid. Further investigations are required to understand why the cooking time increases when the soaking time is over 48 h.

In all the treatments, it was observed that the beans did not absorb water and swell at a uniform rate during soaking. While some grains doubled their size, others (about 25% of the total seed) remained unchanged, even after soaking for 96 h. This had an influence on the cooking time as not all seeds cooked at the same rate. This characteristic was more pronounced in the cream- than the mottled-colored grains and was not uniform for all samples subjected to the same treatment. In the experiments that followed, only the beans that were swollen were selected to ensure uniform evaluation of the treatments.

Effect of alkalinity and acidity on cooking time of *Mucuna* seed

The effect of boiling immature beans in alkaline and acid medium on the cooking time is indicated in Table 1, while Table 2 shows the effect of these treatments combined with soaking on the cooking time of the mature beans.

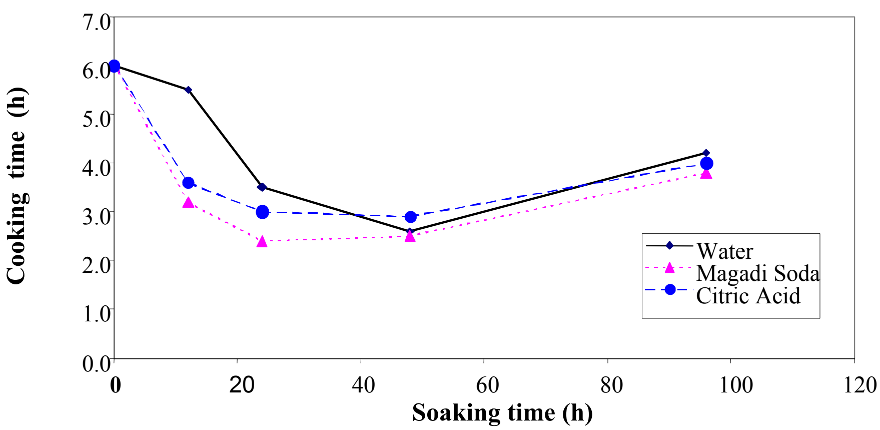

Figure 1. Relationship between soaking time and cooking time of mature *Mucuna* beans in different media.

Table 1. Effect of boiling immature *Mucuna* bean in alkaline and acid medium compared to boiling in water.

Treatment	pH	Cooking time (h)
Water	6.8	1.2
Magadi soda	7.2	0.8
Citric acid	3.2	1.0
Maize cob ash	7.9	0.8
Bean stover ash	7.6	0.9

Table 2. Effect of 48-hour soaking followed by boiling in water, or in alkaline or acid medium on the cooking time of mature *Mucuna* bean.

Treatment	Cooking time (h)	Observations during cooking
Water	4.5	Colour of the cooking water turned slightly brown; slight frothing observed.
Citric acid	2.5	Colour of the cooking water remained clear; seed coats not easily removed; no frothing observed.
Bean stover ash	1.8	Colour of the cooking water very dark brown; formation of froth during cooking; seed coats softened and easily removed within 0.5 h of boiling.
Magadi	1.4	Observations similar to cooking in bean stover ash solution.
Maize cob ash	1.2	Observations similar to cooking in bean stover ash solution.

Immature beans cooked much faster and more uniformly than the mature beans. It is evident from Tables 1 and 2 that alkaline media greatly reduced cooking time of both immature and mature beans. For mature beans, cooking times were 1.2, 1.4, and 1.8 h in maize cob ash, Magadi and bean stover ash solutions, respectively, in comparison to 4.5 h in water. The alkaline solutions had a tenderizing effect on the beans which, when combined with soaking improved cell membrane permeability, reducing cooking time. Less reduction in cooking time was observed when the beans were boiled in citric acid. This is presumably because acid alters the structural properties of starch in the seed, resulting in a delay in starch gelatinization. The seed does not therefore attain the soft texture that is an indication of adequate cooking. The extent of starch gelatinization has been shown to influence the texture of cooked foods (Leach, 1965).

Observations made during cooking of mature beans are indicated in Table 2. When alkaline medium was used, the cooking water turned very dark brown. If the cooking water was not discarded, the cooked beans had a very undesirable dark colour. In acid medium the cooking water remained clear. This indicates that different reactions occurred during the cooking process. Szabo and Tebbett, (2002) reported the formation of melanin compounds which are dark coloured during the oxidation of L-Dopa. Takasaki and Karakishi, (1997) also reported that the oxidation products of L-Dopa coagulate with SH groups of proteins (e.g, cysteine) to form a cross-link. This leads to polymerization of proteins and creating compounds that are readily oxidizable at high pH, which forms dark-coloured compounds. Citric acid acts as an anti-oxidizing agent and may have prevented the oxidative reactions. This could have caused the clear colour of the cooking medium. The cooking water of immature beans also showed similar colour changes. Moreover, before cooking, the immature seed developed intense browning most probably due to enzymatic oxidation of polyphenolic compounds. This browning was reduced when the seed was put in water immediately after removal from the pods. Removing the beans from the green pods was not as easy as it is with common beans and other food legumes.

Proximate composition

The proximate composition of immature and mature *Mucuna* beans is shown in Table 3. Immature beans had higher content of crude protein, total ash and crude fat but lower content of crude fibre and carbohydrates than the mature beans. Immature beans had slightly higher L-dopa content than the mature beans. This observation is similar to the findings of Prakash and Tewari (1999) who found that L-Dopa content was highest in half-mature beans.

Table 4 shows the effect of boiling in water, alkaline and acid medium on the proximate composition of immature beans while Table 5 shows the effect of the above treatments combined with soaking on mature beans.

All the processing methods employed caused some significant ($p<0.05$) changes from the raw beans in the proximate composition of both immature and mature *Mucuna* beans. Boiling in plain water increased the protein content of the immature beans by 19.9% and that of the mature seed by 24.3%. Similar observations were made by Ukachukwu and Obioha, (1997). Boiling the beans in alkaline and acid media also increased the protein from the raw seed content except for the immature bean boiled in citric acid where the protein content reduced by 2.7%. In the immature state, it is possible that most of the proteins are present as free amino acids of low molecular weight that may be easily hydrolyzed or solubilized and lost into the cooking water.

The fibre content of both immature and mature beans was greatly reduced by boiling them in alkaline and acid media compared to plain water. Boiling in Magadi caused the highest reduction in fibre followed by bean stover ash and maize cob ash. The reduction in citric acid was less than in alkaline media. This reduction in alkaline media could be solely attributable to the loss of the seed coats during cooking. The loss of fibre improves the nutritional value of *Mucuna* because fibre is an undesirable component of legumes due to its effect of binding of nutrients like proteins and minerals, which makes them unavailable.

Table 3. Proximate composition (dry matter basis) and anti-nutritional factors of raw immature and mature *Mucuna* seed.

Bean type	Crude protein	Total ash	Crude fibre	Crude fat	Carbohy-drates	L-Dopa	Trypsin inhibitors	Tannins
	- - - - - -	- - - - - -	- - - - - -	%	- - - - - -	- - - - - -	(TIU mg^{-1} protein)	(mg 100 g^{-1})
Raw immature	36.6	4.5	4.6	6.8	33.1	5.89	N.A.	N.A
Raw mature	23.5	2.8	6.2	5.9	43.8	5.75	27.18	26.30

N.A.= not analysed

Table 4. Proximate composition (% dry matter basis) of raw immature *Mucuna* beans, and immature beans cooked by boiling in water, and in alkaline and acid medium.

Treatment	Crude protein	Total ash	Crude fibre	Crude fat	Carbohydrates
Raw immature seed	36.6 a (0)	4.5 d (0)	4.6 d (0)	6.8 d (0)	33.1 a (0)
Plain water	43.9 d (+19.9)	3.4 c (-24.4)	3.4 c (-26.1)	6.2c,d (-8.8)	36.7 b (+10.8)
Magadi	40.4 c (+10.4)	2.9 b (-36.6)	0.8 a (-82.6)	4.8 b (-29.4)	39.9 c (+20.5)
Citric acid	35.6 a (-2.7)	3.9 c,d (-13.3)	2.2 b (-52.2)	5.8 c (-14.7)	47.5 d (+43.5)
Bean stover ash	38.1 b (+4.1)	2.2 a (-51.1)	0.9 a (-80.4)	3.4 a (-50.0)	39.7 c (+19.9)
Maize cob ash	38.9 b (+6.3)	2.3 a (-48.9)	0.9 a (-80.4)	3.3 a (-51.4)	40.6 c (+22.7)

Means in the same column followed by the same letter were not significantly different at p>0.05 by Duncan's Multiple Range Test
Values in parenthesis indicate % change from raw seed. The data are means of 3 replications.

Table 5. Proximate composition (% dry matter basis) of raw mature *Mucuna* seed, and mature beans cooked by boiling in water, and in alkaline and acid medium after 48 hr soaking.

Treatment	Crude protein	Total ash	Crude fibre	Crude fat	Carbohydrates
Raw mature seed	23.5 a (0)	2.8 d (0)	6.2 d (0)	5.9 c (0)	43.8 a (0)
Plain water	29.2 e (+24.3)	2.2 c (-21.4)	4.2 c (- 32.3)	5.9 c (0)	45.2 b (+3.2)
Magadi	28.1 d (+19.5)	1.8 b (-35.7)	1.6 a (-74.2)	5.7 b (-3.4)	48.5 c (+10.7)
Citric acid	26.7 c (+13.6)	2.2 c (-21.4)	2.6 b (-58.1)	5.3 a (-10.2)	47.8 d (+9.1)
Bean stover ash	28.7 d (+22.1)	1.1 a (-60.7)	1.6 a (-74.2)	5.8 b,c (-1.8)	45.9 b (+4.8)
Maize cob ash	25.8 b (+9.8)	1.2 a (-57.1)	1.8 a (-70.9)	5.6 b (-5.1)	49.6 d (+3.2)

Means in the same column followed by the same letter were not significantly different at p>0.05 by Duncan's Multiple Range Test
Values in parenthesis indicate % change from raw seed. The data are means of 3 replications.

The crude fat and total ash content also decreased from the raw seed as a result of all the processing treatments tested. These results agree with the reports of Udedibie and Mba (1994) and Udedibie *et al*. (1996) for pigeon pea and jackbeans, respectively. Ukachukwu and Obioha (1997) also observed a reduction in ash and fat contents by soaking and boiling *Mucuna* seed in water. For mature seed, citric acid reduced the fat content more than the alkaline treatments. The loss may have been due to leaching of some fats into the cooking water or volatilization of fats during boiling. All the treatments also increased the carbohydrate content of both immature and mature seed.

Effect of germination combined with boiling on the proximate composition of mature *Mucuna* seeds

Table 6 shows the proximate composition and the content of some anti-nutritional factors of mature *Mucuna* beans germinated for 5 and 7 d and boiled with or without dehulling. Significant differences ($p<0.05$) were observed between samples germinated for 5 or 7 d with respect to all the nutrients determined. The effect of dehulling was only significantly different with respect to the protein and fibre. Beans that were dehulled before boiling had higher protein content and less fibre than those boiled without dehulling. The protein content was lowest when the beans were germinated for 7 d and boiled without dehulling. Removing the hulls caused the reduction in the fibre content. Boiling the germinated beans caused significant differences ($p<0.05$) in all the nutrients determined.

Effect of different processing methods on the anti-nutritional factors of *Mucuna*

Table 7 shows the content of L-Dopa, trypsin inhibitors and tannins and the percent reduction (values parenthesized) after boiling whole and sliced mature beans in alkaline and acid media and by germination combined with boiling. Boiling whole mature beans in Magadi solution resulted in the highest reduction of L-Dopa (59.3%), while boiling in maize cob ash and bean stover ash solution reduced the L-Dopa by 58.1 and 47.4%, respectively. Citric acid reduced the L-Dopa by 49.7%. Slicing the beans further reduced the L-Dopa content by 80.5% in Magadi, 69.6% in citric acid, 74.8% in maize cob ash solution and 69.5% in bean stover ash solution. Boiling in water and germination for 5 d combined with boiling reduced the L-Dopa by only 37.0%. Increasing the duration of germination to 7 d further reduced the L-Dopa content by 41.7%.

The content of trypsin inhibitors was reduced to a greater extent (89.7%) by boiling the seed in water than the other treatments. Germination for 5 and 7 d reduced the content by 84.5 and 85.4%, respectively. Beneficial effects of germination on trypsin inhibitory activity have been reported in literature. Similarly, El-hag *et al*. reported a reduction of about 50% in red kidney beans during a 10-day germination, while Sathe *et al*. (1983) found a reduction of 62.9% in 5-day germinated great Northern beans. The tannin content was more reduced in alkaline than acid medium or plain water. Germination also reduced the tannin content if the beans were dehulled before boiling. This indicates that a greater percentage of tannins are present in the seed coat.

Table 8 shows the L-Dopa content of raw immature *Mucuna* beans and the percent reduction when boiled in water, alkaline and acid medium. Boiling in Magadi reduced the content more than the other treatments. This was followed by maize cob ash solution with 40.4% reduction. The reduction in L-Dopa content of the immature bean was generally less than the reduction in mature beans.

Table 6. Proximate composition (% dry matter basis) of mature *Mucuna* beans germinated for 5 or 7 d combined with boiling with or without dehulling. The data are means of 3 replications.

Germination time (d)	Treatment	Protein	Ash	Fibre	Fat	Carbohydrates
0	Raw seed	23.5 c	2.8 d	6.2 c	5.9 a	43.8 a
5	Not dehulled, not boiled	23.6 c	1.8 c	9.3 d	5.6 a	46.1 b
5	Dehulled , not boiled	27.8 d	1.8 c	3.0 a	5.9 a	46.2 b
5	Not dehulled, boiled	27.4 d	1.3 b	10.8 e	4.3 d	47.3 d
5	Dehulled and boiled	34.1 f	0.9 a	3.4 b	5.4 b	48.8 e
7	Not dehulled, not boiled	21.5 b	1.9 c	10.2 e	5.0 b	46.6 c
7	Dehulled, not boiled	28.9 d	2.3 d	2.8 a	4.7 bc	47.8 e
7	Not dehulled, boiled	20.9 a	1.4 b	11.0 f	4.6 bc	46.2 b
7	Dehulled and boiled	30.3 e	0.9 a	3.7 b	5.6a	46.9 c

Means in the same column followed by the same letter were not significantly different at $p>0.05$ by Duncan's Multiple Range Test

Table 7. Effect of different processing methods on some anti-nutritional factors of mature *Mucuna* bean. Values in parentheses indicate % change.

Processing method	L-Dopa (%)		Trypsin inhibitors (TIU mg^{-1} protein)	Tannins (mg 100 g^{-1})
	Whole beans	Sliced beans		
Raw mature seed	5.75 (0)	5.75 (0)	27.18 g (0)	26.30 d (0)
Boiling in water	4.42 (-23.1)	-	2.80 a (-89.7)	25.81c (-1.9)
Boiling in Magadi	2.34 (-59.3)	1.12 (-80.5)	8.35 e (-69.3)	23.80 a (-9.5)
Boiling in citric acid	2.89 (-49.7)	1.75 (-69.6)	5.83 d (-78.5)	25.62 c (-2.7)
Boiling in maize cob ash	2.41 (-58.1)	1.45 (-74.8)	8.81 e (-67.6)	23.84 a (-9.5)
Boiling in bean stover ash	3.02 (-47.4)	1.73 (-69.5)	8.93 e (-67.1)	24.12 b (-8.4)
Germination 5 d, dehulling, boiling 1.5h	3.62 (-37.0)	-	4.20 c (-84.5)	24.20 b (-8.0)
Germination 7 d, dehulling, boiling 1.5h	3.35 (-41.7)	-	3.95 b (-85.4)	24.04 b (-8.7)
Germination 5 d, no dehulling, boiling 1.5h	-	-	7.47 e (-72.5)	26.21 d (-0.3)
Germination 7 d, no dehulling, no boiling	-	-	23.60 f (-13.7)	26.01 d (-1.1)

Means in the same column followed by the same letter were not significantly different at p>0.05 by Duncan's Multiple Range Test.

Table 8. L-Dopa content of immature *Mucuna* seed as affected by boiling in water and in alkaline and acid medium.

Treatment	L-Dopa	Change (%)
Raw immature seed	5.89	0
Water	4.55	-22.8
Magadi	3.38	-42.6
Citric acid	3.94	-33.1
Maize cob ash	3.51	-40.4
Bean stover ash	4.16	-29.4

Consumer acceptability of cooked *Mucuna* seed

Table 9 shows the panelists' mean scores for taste, colour and texture of *Mucuna* bean boiled in Magadi soda, maize cob ash and citric acid compared to the common bean. Cooking the beans in Magadi soda enhanced the taste and texture of *Mucuna,* although it was not as acceptable as the common bean. Citric acid gave a very acceptable color, but the farmers did not like the taste and the texture of the beans. The beans could not cook to the desired soft texture. The colour of beans cooked in alkaline was not very acceptable to the panelists.

Table 9. Panelists' mean scores for taste, color and texture of *Mucuna* seed compared with common bean (1- like very much, 4 – dislike very much).

Treatment	Taste	Color	Texture
Magadi soda	1.61 b	2.60 b	1.03 a
Citric acid	3.55 d	1.01 a	3.90 b
Maize cob ash	2.52 c	2.57 b	1.20 a
Common bean	1.00 a	1.10 a	1.00 a

Means in the same column followed by the same letter were not significantly different at p>0.05 by Duncan's Multiple Range Test.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The study showed that soaking is necessary before cooking mature *Mucuna* seed. The optimum soaking time was found to be 48 h. Using mild alkaline or acid solution can reduce the soaking time. However, it is possible that such treatments may cause leaching of nutrients into the soaking water. The study also established that the cooking time is greatly reduced when the beans are boiled in an alkaline solution; acid medium reduces cooking time less. Of the different types of alkaline additives tested, Magadi soda proved to be more effective in reducing both the cooking time and the content of fibre and L-Dopa. It also enhanced consumer acceptability of the beans. Increasing the duration of germination from 5 to 7 d also reduced the content of L-Dopa and other anti-nutrients.

The different cooking characteristics of the beans observed in acid and alkaline media signify different reactions and probably differences in the mode of removal of L-Dopa. Further investigations are therefore required to understand these reactions in order to ensure that no toxic compounds are generated. Furthermore, the protein quality of the bean as affected by the alkaline and acid media needs to be assessed. During the study, it became apparent that individual *Mucuna* seeds vary considerably in their ability to absorb water and swell during soaking. This, in turn, affects the cooking time, as individual seeds do not cook uniformly. Possible causes for this 'hard-to-cook' characteristic of different *Mucuna* seeds need further investigation.

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