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African yam bean: optimisation of thermal treatment for degradation of antinutrients in the seeds

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled "African yam bean: optimisation of thermal treatment for degradation of antinutrients in the seeds" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 21st April 2024

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Abstract

African yam bean is a neglected and underutilised leguminous plant known for its adaptability to diverse agroecological zones in West and East Africa and its rich protein content which could help alleviate the issue of malnutrition and add to food security in Africa. There is however a decline in the use of the crop due to several reasons, including the presence of antinutrients. The seeds are traditionally used as a pulse, and the tubers are also consumed. The purpose of this project was to assess the effect of soaking and the ratio of water to seed during cooking on the antinutrient content of the African yam beans and their functional properties.

The seeds were subjected to different treatments by soaking for 24 hours, cooked in different ratios of water, and processed by grinding, and finally, the content of antinutrients (tannins, saponins, and phytate) was also determined spectrophotometrically. Functional properties (water absorption capacity, oil absorption capacity, water solubility index, foaming capacity, and emulsifying capacity) were determined by standard methods.

The results depicted differences in the antinutrient contents of the seeds based on the different treatments the seeds were subjected to. The content of antinutrients decreased as the ratio of water used to cook the seeds also increased, with the lowest antinutrient content observed as 2.8 ± 0.05 mg/g of tannin concentration, 1.2 ± 0.07 mg/g of saponin concentration and 2.7 ± 0.05 mg/g of phytate concentration. There was however no significant difference in the functional properties of the seeds when the seeds were subjected to different treatments. The findings also indicated that soaking African yam bean seeds in water for 24 hours before cooking in a ratio of 1:7 is enough to reduce cooking time, reduce the quantity of antinutrients in the seeds to make them safe enough for food consumption, and the functional properties of the seed are also not affected which makes the seeds subjected to this treatment good for industrial use. Given the high cost of energy in developing nations such as Ghana, the 70% decrease in cooking time achieved by pre-soaking the seeds in sodium bicarbonate is significant.

Keywords: *Sphenostylis stenocarpa*, antinutrients, seeds, cooking time, African neglected crop

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List of abbreviations

AYB	African Yam Bean
DNA	Deoxyribonucleic acid
CHO	Carbohydrate
NR	Not reported
IITA	International Institute of Tropical Agriculture.
IAR&T	Institute of Agricultural Research & Training.
NACGRAB	National Centre for Genetic Resources and Biotechnology
WAI	Water absorption index
WHC	Water holding capacity
HPLC	High-performance liquid chromatography
GC	Gas chromatography
IR	Infrared spectroscopy
NMR	Nuclear magnetic resonance
PCR	Polymerase chain reaction
WAC	Water absorption capacity
OAC	Oil absorption capacity
FC	foaming capacity
EC	Emulsifying capacity
WSI	Water solubility index
DW	Distilled water

1. Introduction

There has been a growing worldwide concern about food security and sustainability in recent years. Many of Africa's native food crops, which have the potential to reduce nutritional food insecurity, are currently underutilized and neglected. One of these crops with exceptional nutritional potential is the African yam bean. I developed a personal interest in African yam bean after working on it during my bachelor's Thesis (Serwaa-Darko, 2018) African yam bean (AYB), also known as *Sphenostylis stenocarpa*, is a neglected and underutilized leguminous plant genetic resource of the family Fabaceae and subfamily Faboidae. It is a small genus with only seven species (Potter & Doyle 1992a). Humans' reliance on plants for survival is linked to developing specific knowledge about plant value, use, management, and conservation.

Most Sub-Saharan African households' diets are lacking in protein and critical nutrients, particularly among the rural poor (Duodu & Apea-Bah 2017a). Some people cannot afford to buy animal protein (fish, meat, and poultry products) for their meals; therefore, they look for an alternate source, like legumes. Legumes are utilized as a subsistence meal in practically every corner of the world, and they are frequently consumed with grains as a replacement source of protein and calorific value for people and cattle. Over the years, the major staple crops have received great attention in strengthening food security, with little regards to underused crops with enormous potential as a replacement protein source and nutrition security crop. One of these crops is the African yam bean (Ojuederie et al. 2020a). In Ghana, animal protein is more expensive than plant protein; and the African yam bean is one plant that might help with protein consumption.However, because of several constraints, the crop is on the verge of extinction. Although little is known about the African yam bean, it appears to require a humid tropical environment with well-drained soil. The plant also requires support to develop properly, and African farmers frequently use the same stakes that support yam plants. It also takes roughly a year to harvest the crop.

Despite its nutritional advantages, the African yam bean has several constraints or challenges with its use. The presence of significant antinutritional components such as tannins, saponins, oxalate, phytate, trypsin inhibitors, and lectin, as well as a long boiling time and low seed yield, are important limits to its production and use. In numerous animal models, raw or badly cooked legume seeds have been demonstrated to contain toxic substances that induce development failure, poor food consumption, pancreatic enlargement and hyperplasia, and decreased enzyme function. The presence of trypsin inhibitors has been linked to the growth-inhibiting action of raw navy beans given to rats (Onyeike & Omubo-Dede 2002). These characteristics, along with the hardness of the seed coat, lengthen the time required to boil and prepare the beans, which are frequently consumed alone or with yam, maize, and rice. These antinutrients have deterred consumers and subsistence farmers from using and accepting AYB. Breeders' present germplasm basis for genetic enhancement is very limited. African yam bean is one of the 400 underutilized leguminous crops of the lowland tropics, and it is presently vulnerable to genetic erosion, which would surely weaken the genetic base and, eventually, extinction. One strategy for mitigating nutritional, environmental, and economic risks might be to use underused crops such as the African yam bean (Jaenicke & Pasiecznik 2009).

2. Literature review

2.2 African yam bean

African yam bean (*Sphenostylis stenocarpa*) is one of seven species of the genus *Sphenostylis* E. Meyer (Leguminosae; Papilionoideae; Phaseoleae) It is the most widely distributed and morphologically variable species in the genus (figure1), and the most ecologically significant and most important economically (Potter & Doyle 1992a)

The African yam bean, is found in dry woodlands, as well as open or wooded savannas, primarily in tropical and Southern Africa.It is a perennial climbing plant with morphotypes that can grow prostrate or upright and range in height from 1-3m. It has trifoliate leaves that are 2.7 to 13cm long and 0.2 to 5.5cm wide. The inflorescence is a raceme with pink and purple flowers that mature in an acropetal mode, with a little bent backward characteristic of the Fabaceae (Adewale et al. 2012). Northeast tropical Africa (Chad and Ethiopia), east tropical Africa (Kenya and Uganda), west-central tropical Africa (Burundi and Zaire), and West Africa are the centers of variety for African yam bean (Ghana, Guinea, Mali, Niger, Nigeria, and Togo), (Oagile et al. 2007). AYB produces two essential products, the underground root tuber, and the edible yam bean seeds, which grow in pods above the ground

African yam bean has been cultivated for its edible tuber and for its seeds which have high nutritional values. The amino acid (lysine and methionine) content is greater than in pigeon peas, cowpeas, and Bambara groundnut. African yam bean's amino acid profile (g/100 g) included lysine (6.12), histidine (3.10), arginine (6.47), aspartic acid (9.12), glycine (4.05), valine (4.96), and phenylalanine (5.05) (Baiyeri et al. 2018). Its lysine and methionine levels were equivalent to or higher than that of soybean protein, and it is comparable to whole chicken eggs in terms of protein content. Its protein profile is comparable to that of other African root crops such as yam and sweet potatoes, and it has about ten times the protein content of cassava tubers, while the necessary proteins in African yam bean are similar to those in soybeans (Ekop 2006). According to (Potter & Doyle 1992a) this species holds significant economic importance and exhibits a wide distribution and considerable morphological variability within the genus. According to (Verdcourt & Døygaard ,2001), the plant has perennial characteristics, with stems that frequently display a reddish colouring. These stems are either glabrous or sparsely puberulus, and toward their roots, they possess a woody texture. Tubers, which are abundant in starch, are formed by roots and function as perennation organs when the aboveground components perish in arid conditions (National Academy of Sciences, 1979; Klu et al., 2001). The tubers are very similar to sweet potatoes, its flesh is white and watery. There seem to be some evidence that yields of seeds and tubers are inversely related (Hutchinson &Dalziel, 1954). The tubers take up to five to eight months to mature and serve as organs of perennation as above parts usually wither and die in dry weather (Porter, 1992). The plant specimens exhibit a spectrum of growth patterns, ranging from fragile, low-lying vines in certain untamed populations to sturdy climbers that may attain heights of several meters. The foliage exhibits pinnate trifoliate characteristics, wherein the leaflets assume linear, lanceolate, ovate, or elliptic shapes, depending on the specific landrace. The plants exhibit the presence of purple to magenta-coloured flowers arranged in pseudo racemes. According to (Potter & Doyle 1992b) the standard petals of the individual flowers have a twisted morphology. The process of flower production typically takes between 100 to 150 days after the germination of seeds. After pollination and fertilization, the flowers develop into pods that possess a somewhat woody texture and may reach a length of up to 30cm. (Klu et al. 2001), stated that the pods consist of a range of 20 to 30 seeds, which reach maturity about 30 days after fertilization. (Tindall, 1983) indicates that the seeds exhibit a range of colours including brown, white, speckled, or marbled. They possess a distinct dark brown hilum border and are characterized by an ellipsoid or spherical shape. In terms of size, the seeds measure roughly 9 by 7mm. The botanical characteristics of the African Yam Bean has been documented in publications (Potter & Doyle 1992b), (Verdcourt & Døygaard.,2004).

African yam bean tolerates wide geographical, climatic, and edaphic ecologies. The stretch of the environment where it thrives lie within the latitude of 15° North to 15° South and the longitudes of 15° West to 40° East of Africa (Adewale et al., 2008). There is no record of the origin of the crop in any other continent except Africa (Potter & Doyle, 1992). Hence, the above geographical catchments could be referred to as the Centre of diversity of AYB. This confirms the common claim that the crop is a tropical African legume. The sustainability of African yam bean for the diverse ecologies (Barth et al., 2005) suggests that it can potentially serve as an important crop for food security since it can tolerate varied soil and climate condition. This quality confers on it an ecological advantage over most conventional legumes. Contrary to the remark of (Klu et al., 2001) on the nearness of the crop to extinction, the ability of the crop to survive in diverse agro-ecological conditions of Africa must have aided its continual existence over times. Presently in Ghana and Nigeria, there is a dwindling interest in the production of African yam beans among the farmers (Klu et al., 2001). Only a very small sector of farmers appreciates its cultivation, hence they are the holder of the crops genetic resources (Adewale et al., 2012).

Figure 1: Variants of African yam bean

2.2.1 Cultivation of African yam bean

The cultivation of African yam bean is prevalent in several nations located in West Africa, with a particular focus on Guinea, the Ivory Coast, Nigeria, and Togo. This cultivation extends to other regions in central and equatorial Africa as well (Tindall, 1983). The cultivation of this plant mostly occurs as a minor intercrop alongside large crops, such as maize (*Zea mays*) and cassava (*Manihot esculenta*), particularly in some regions of Ghana. In these settings, the plant exhibits a twining behaviour, using the stems of the big crops for support (Klu et al., 2001). (Potter, 1992) conducted a comprehensive investigation on the species, whereby several observations were recorded. African yam bean is cultivated as an annual crop in significant production regions of Zaire. The propagation of this crop involves the planting of seeds during September and October. Subsequently, the tubers are harvested in the period between March and April of the following year. Similarly, the African yam bean is cultivated as an annual crop for seed production and consumption in several regions of Nigeria, (Aremu et al. 2016) Nevertheless, it has been noted that plants in these regions also display a perennial behaviour, whereby they regenerate from rootstocks on an annual basis after the end of the dry season. Remarkably, several plants have been able to sustain this pattern for over two decades. Plants cultivated from seeds have a comparable developmental timeline to tubers, spanning from the planting phase in April to July till the harvest period in December. AYB does not get significant emphasis in these mixed cropping systems, since it derives advantages from the intermittent cultural methods used for the primary crops. Regrettably, (Okoye et al. 2017) observed a decrease in the output of African yam bean. The availability of this commodity in local marketplaces has become restricted, despite its competitive pricing in comparison to cowpea or groundnut. Currently, there is a lack of improved varieties of African yam bean, resulting in farmers relying on landraces obtained from past harvests or locally sourced seeds for crop establishment. The restrictions to large-scale commercial production of the AYB have been noted attributed to the absence of improved cultivars with a dwarf erect height, shorter growing time, and seeds with testas that are simpler to cook (Klu et al., 2001).

2.2.2 Process of planting and cultivation of African yam beans in Kumasi, Ghana

(Jibril Farms are dealers in rare African plant seeds and agricultural products in Kumasi, Ghana)

There is no uniform way of planting the AYB, it can be done either on flat land or on ridges (figure 2) depending on the part of the crop you are planting for, the beans or tuber. Planting on ridges is preferred to harvest both tubers and beans. African yam bean takes more than 3 months to produce beans and more than 5 months to produce tubers. It is preferred to start planting during the planting season of the area. The planting distance of African yam bean is usually 80cm by 40cm inter and intra row respectively. Weed control can be done after three weeks of planting or when the overgrowing of weeds is noticed on the farm. Weed control in AYB is usually done by hand hoe and is continued after final harvesting. Staking (Figure 3) is also needed when vigorous growth of the vine is noticed to avoid them creeping on the floor. After two months of planting the plants form canopies and bring shadow on the farm. Flowering begins after the tenth week of planting, (figure 4), and at this stage insect and pest infestation is very great, and organic pesticide is recommended. Production of flowers and pods continues throughout the lifespan of the crop. The pods start to show maturity or drying (figure 5) within 120-150 days. Harvesting of the dry pods commences when they are fully dried or when their colour changes to brownish-black (figure 6).

Harvesting of the tuber starts when the crop begins to slowly dry out. The tubers must be carefully dug to prevent damaging or cutting them.

Figure 2: African yam bean-seedlings(Jibril farms,2023)

Figure 3: African yam bean-field (Jibril farms, 2023)

Figure 4: African yam bean (Jibril farms, 2023)

Figure 5: African yam bean-seed-pods (Jibril farms, 2023)

Figure 6: African yam bean-matured (Jibril farms, 2023)

2.2.3. Nutritional composition of African yam bean.

African yam bean is high in protein and fiber content and is a good source of vitamins and minerals. It is also a low glycemic index food, which means it does not cause rapid and large increases in blood glucose levels. The protein content of AYB is approximately 25-30%, and is of good quality, with a high proportion of essential amino acids. It contains all the essential amino acids, as well as a good amount of lysine, which is important for bone and muscle health (Adewale et al, 2012).

The fiber content of African yam bean is also high, at around 13-15%. This is beneficial for digestive health, as well as reducing the risk of chronic diseases such as diabetes, cardiovascular disease, and cancer (Ojuederie et al. 2020). In terms of vitamins and minerals, the African yam bean is an excellent source of several B vitamins, including thiamin, riboflavin, niacin, and folate. It is also a good source of zinc and iron, which are important for the body's immune system and for the formation of red blood cells

Various researchers have published the proximate composition of African yam bean over the years, with varied values, as presented in Table 1. Carbohydrates (49.88-63.51%) and protein (19.53-29.53%) are the two most abundant components of AYB, with ash (1.86-5.35%), fat (1.39-7.53%), and fiber (2.47-9.57%) appearing in trace levels. Several factors, including seed acquisition, planting location, agronomic techniques, and the season of the year when the bean was planted, may impact its proximate composition. Some authors have studied different variants of AYB and reported slight differences in protein content 22.33–25.78% (Adeyeye et al. 1994), 22.72–26.68% (Ajibola et al. 2016). Protein concentration varied with processing conditions, according to other investigators. (Ndidi et al. 2014) for example, discovered a minor but noticeable drop in the protein content of boiled and roasted AYB. When boiled AYB was compared to roasted grain (about. 6%), it revealed a 9% loss in protein. (Nwosu 2013) also showed a small rise (2.5 and 5%, respectively) in the protein content of AYB after 24 and 48 hours of steeping, followed by germination after 96 hours. The author ascribed the rise to protease production during germination (Nwosu 2013). Both authors' findings support the impact of different treatments on the protein content of the bean.

The presence of amino acids (8 essential and 9 non-essential) has been observed, with glutamic acid, aspartic acid, leucine, and lysine being the most common (Ade-Omowaye et al. 2015). Sulphur-containing amino acids - cysteine and methionine - were only found in trace amounts, as in most other pulses (Ade-Omowaye et al. 2015). In addition, the amino acid makeup of the bean differs amongst varieties (Adeyeye et al. 1994). Because of the availability of amino acids, the bean is a great fortifying choice for many cereal-based diets that are protein-deficient, and as such, it may be used to address the problem of kwashiorkor and marasmus in new-borns.

The bean has a low lipid content, which is to be anticipated given that AYB is categorized as a pulse. Unlike oil seeds, pulses have relatively little fat content, generally less than 10% but occasionally slightly greater. Alpha-linolenic and linoleic acid are found in AYB (Ade-Omowaye et al. 2015). The same author also reported the oleic acid content (34.40 g/kg), which was found to be greater than in some other pulses. All of these are crucial in human nutrition since they are beneficial to the overall health of the human body but cannot be synthesized by the body and must therefore be obtained from diet. Because of its low-fat content, AYB is also easy to handle, process, and store (Abioye et al. 2015).

The carbohydrate (CHO) content of African yam beans (49.88-63.51%) is equivalent to that of other legumes. Various writers have reported various AYB CHO levels. Variations in CHO concentration as well as other chemical compositions can be linked to variances in sourcing locations, genetic differences, processing processes, and agronomic and climatic circumstances of where they are cultivated. This is feasible given that the grains vary in size, shape, and colour (Ade-Omowaye et al. 2015) African yam bean has a crude fibre concentration ranging from 2.47 to 9.57%, both soluble and insoluble. Because fibre consumption decreases the prevalence of lifestyle illnesses among consumers, AYB are a potential source of vital functional foods for consumers. Furthermore, with increased consumer awareness of the need to eat nutritious meals, AYB can be a source of low-cost, health-beneficial food commodity for people of all socioeconomic backgrounds.

Except for specific cultivars, the bean has a low moisture content (1.93-13.30%), which is under the recommended moisture threshold for safety (14.50%) (Abioye et al. 2015), but moisture level is heavily dependent on postharvest drying, handling, and storage circumstances.

All these studies have demonstrated the significance of this underutilized pulse, which may be employed in the development of innovative culinary items as well as functional meals that are necessary for healthy living. The proximate composition results for AYB correspond favourably with those published for other popular pulses such as cowpea (Preet & Punia 2000), Bambara groundnut, chickpea, and common bean (Nnamani et al. 2017). Table 2 provides the proximate composition of African yam bean in comparison with some common and underutilised legumes

Table 1:Proximate Composition of African yam bean from different authors in percentage

Region of purchase of sample	Ash	Protein	CHO	Fibre	Fat	Moisture	References
Nsukka	4.55	19.62	NR	8.45	3.00	NR	(Nwokolo 1987)
Ekiti	2.60	20.51	50.24	6.09	12.20	8.36	(Adeyeye et al. 1994)
Owerri	3.29	23.24	58.04	5.31	1.64	9.43	(Nwosu 2013)
South Kudana	2.64	21.78	63.51	9.29	2.84	9.23	(Ndidi et al. 2014)
Southwest Nigeria	NR	19.53	NR	NR	1.93	12.04	(Ade-Omowaye et al. 2015)
Southwest Nigeria	4.30	24.96	59.84	6.26	2.70	1.93	(Adamu et al. 2015)
Enugu	3.66	27.66	49.88	9.57	4.29	4.94	(Ikpa 2015)
IAR&T & NACGRAB	3.47	29.53	52.59	2.75	2.80	9.09	(Abioye et al. 2015)
IITA Ibadan	1.89	24.31	58.64	2.47	1.88	13.30	(Ajibola & Olapade 2016)
IITA Ibadan	4.28	22.46	53.86	6.47	3.59	9.52	(Baiyeri et al. 2018)
Cross River	5.35	21.61	NR	7.00	5.12	NR	(Anya & Ozung 2019)

NR: Not reported, CHO: Carbohydrate. IITA: International Institute of Tropical Agriculture. IAR&T: Institute of Agricultural Research & Training. NACGRAB: National Centre for Genetic Resources and Biotechnology.

Table 2:Proximate composition of African Yam Bean in comparison with some common and underutilized legumes

Legume	Ash	Protein	Carbohydrate	Fat	Fibre	Moisture	References
African Yam Bean	1.86–5.35	19.53–29.53	49.88–63.51	1.39–7.53	2.47–9.57	1.93–13.30	(Nwokolo 1987), (Adeyeye et al. 1994), (Nwosu 2013), (Abioye et al. 2015), (Adamu et al. 2015), (Baiyeri et al. 2018).
Cowpea	3.40–4.50	19.00–27.00	56.00–64.00	1.00–4.50	1.30–2.50	6.80–9.10	(Henshaw 2008), (Owolabi et al. 2012).
Soybean	4.40	35.00	35.00	17.00	NR	13.00	(Liu 2012)
Bambara	2.50–3.50	17.00–25.00	53.00–69.00	6.50–8.50	1.80–14.00	NR	(Onimawo et al. 1998), (Olanipekun et al. 2012), (Ade-Omowaye et al. 2015).
Chickpea	3.20–3.90	19.00–25.00	41.1–47.4	4.50–6.00	17.40	7.20–7.40	(Iqbal et al. 2006), (El-Adawy 2002), (Sofi et al. 2020).
Pigeon Pea	3.50–4.05	19.39–22.30	57.16–57.60	1.70–3.24	1.50–5.56	NR	(Jeevarathinam & Chelladurai 2020)

NR: Not reported

2.2.4 Health benefits of African yam bean

African yam bean is a leguminous crop with nutritional and health-promoting attributes. Studies suggest that it is a rich source of essential nutrients, including protein, fiber, vitamins, and minerals (Ene-Obong et al., 2002; Ogunbanwo et al., 2012). The protein content in African yam beans is considered comparable to or even higher than that of other commonly consumed legumes.Furthermore, research has highlighted its potential antioxidant properties, attributed to the presence of phenolic compounds (Oloyede et al., 2015). Antioxidants play a crucial role in neutralizing free radicals and preventing oxidative stress, which is linked to various chronic diseases. Moreover, African yam bean has been investigated for its potential hypoglycemic and antidiabetic effects. Some studies indicate that components in African yam beans may contribute to blood sugar regulation, making it a subject of interest for those managing diabetes (Ogunlakin et al., 2018; Erukainure et al., 2019).

2.2.5 Economic benefits of African yam bean

The economic benefits of the African yam bean have garnered attention due to its potential contributions to agricultural livelihoods and food security. Some economic benefits include its high yield and versatility, The African yam bean is known for its adaptability to diverse agro-ecological zones and soil types. Its ability to thrive in various conditions contributes to increased agricultural productivity, providing farmers with a versatile crop option (Doku, 2002). Another economic benefit is its nutrient-rich seeds, the seeds of African yam bean are rich in protein and essential amino acids. This nutritional profile enhances its market value and economic potential, positioning it as a valuable source of protein for both human and animal consumption (Ugwuona & Aba, 2009). Potential for Industrial use is another benefit, beyond traditional consumption, African yam bean has potential industrial applications. Research indicates its suitability to produce flour, starch, and protein isolates, which can be integrated into food processing and other industries (Falade & Ayodele, 2013; Oluwole et al., 2015). It can also lead to enhanced crop rotation and biodiversity, as incorporating African yam beans into crop rotation systems can have positive effects on soil fertility and structure. Its cultivation supports sustainable agricultural practices, promoting biodiversity and reducing the risk of soil degradation (Bamishaiye et al., 2014). The cultivation and commercialization of African yam bean can contribute to local economic development. By providing farmers with an additional income source, this crop can play a role in poverty alleviation and rural development (Oloyede et al., 2015). It also has drought resistance and climate adaptability, African yam bean's resilience to drought conditions makes it an asset in regions prone to climate variability. Its ability to thrive in challenging environmental conditions can mitigate the impact of climate change on agricultural production (Okpara et al., 2016).

While these economic benefits showcase the potential of the African yam bean, further research and development efforts are necessary to fully unlock its economic value and integrate it into sustainable agricultural systems.

2.2.6. African yam bean's significance in food fortification and enrichment

In the past, African yam bean was used to fortify and improve other less nutritious dishes. Food fortification is the addition of nutrients (macro or micro alike) to foods to compensate for losses that may have occurred during processing. Food enrichment is the addition of nutrients (macro or micro alike) to foods to compensate for losses that may have occurred during processing. Fortification and enrichment of foods poor in key nutrients enhance the nutritional condition of underdeveloped nations where purchasing meals high in animal protein is very expensive, (Bolarinwa et al. 2019). Fortifiers should be accessible and available for successful food fortification so that the influence on the greater population may be felt (Oyeyinka & Oyeyinka 2018). Furthermore, the process of improving the nutritional quality of foods should not be at the expense of their sensory and physicochemical properties.

Many people utilize African yam beans to complement, augment, strengthen, and enhance other staples such as morning dishes (Babarinde et al. 2019), biscuits, and traditional snacks, such as kokoro (Idowu 2014), instant noodles (Effiong et al. 2018), cereal blends (Okoye et al. 2017) and many others. Because of the bean's high protein content, it is an excellent choice for fortification in a variety of dishes. As a result, their application in food fortification and enrichment has the potential to improve food security and human nutrition.

2.2.7 African yam bean use restrictions

Many African legumes have had their use restricted throughout the years due to characteristics that are related to them. The two most significant limitations that have been highlighted by many authors for many years are their difficulty in cooking and the existence of non-nutritional chemicals, also known as antinutrients, (Prasad & Singh 2015), (Ajibola & Olapade 2016), (Duodu & Apea-Bah 2017b). African yam bean is one of several leguminous crops that suffer from these constraints. Because of their difficult-to-cook nature, the crop necessitates a longer cooking time, limiting its usage and processing among the consuming public and homes (Aminigo & Metzger 2005). Prolonged cooking time is expensive, causes significant energy consumption, and leads to the loss of certain key micronutrients that may have leached because of a longer cooking duration, which may harm important nutrients. However, lengthy heating helps to reduce the amount of antinutrients in the bean. Soaking before hydrothermal treatments can reduce the hard-to-cook condition of many pulses, such as AYB, (Ojo 2018). According to this source, hydrating hard-to-cook pulses before boiling is an excellent approach to reducing cooking time and energy usage. According to (Nwosu 2013), malting and germination of AYB before boiling may help shorten the cooking time of this bean.

Aside from the lengthy boiling time, the presence of antinutrients in AYB has also been a limiting factor in its utilization (Oboh et al. 1998). Antinutrients are naturally occurring chemical molecules in plants that can change nutrient absorption and impede metabolic processes (Oboh et al. 1998). If proper processing procedures are not used, these chemicals may interfere with the bioavailability of mineral components such as calcium and iron, (Ghavidel & Prakash 2007). Antinutrients found in AYB include lectin, tannins, phytic acid, oxalate, saponins, stachyose, alkaloid, raffinose, trypsin inhibitors, and hydrogen cyanide (Nwosu 2013), (Ajibola & Olapade 2016), (Duodu & Apea-Bah 2017b). Some authors have proposed specific processing procedures for reducing these chemicals, including soaking, malting, germination, boiling, and roasting (Aremu et al. 2016). It has been observed that soaking AYB for 24 hours prior to boiling is a promising method of decreasing antinutrients (Nwosu, 2013). Germination and malting, according to this source, diminish the antinutrient content. These techniques have also been used to reduce antinutrients found in other comparable pulses, (Vidal-Valverde et al. 1994). Aside from extended and rigorous cooking conditions and antinutrients (Maphosa & Jideani 2017) stated that the limited use of AYB may be attributed to poor yield in specific areas, low seed availability, rigorous labour needs at maturity, a lack of convenient food applications, a low level of awareness, and bloating and flatulence.The production of AYB is limited by several factors, including the lack of quality seeds, inadequate agronomic knowledge, and poor soil fertility.

To address these challenges, potential interventions have been proposed, such as strengthening seed production and storage infrastructure, providing extension services to farmers, and increasing consumer education efforts. Implementing these interventions and others will be essential to unlocking the potential of AYB and ensuring its sustainability in the region (Ajibola & Olapade 2016),

2.2.8 Anti-nutritional properties of African Yam Bean

In contrast to its nutritional potential, previous research performed on under-utilized legumes in Nigeria has shown that the African yam bean has several anti-nutritional chemicals, such as α-galactosidase, inositol phosphate, lectin, and tannins (Oboh et al., 1998).

The presence of antinutrients in African yam bean has been investigated, and while this legume offers numerous nutritional benefits, it contains certain antinutritional factors that need consideration. African yam bean contains tannins, which are polyphenolic compounds. Tannins can interfere with nutrient absorption, particularly minerals like iron and zinc, and may lead to reduced bioavailability of these essential nutrients (Ogunbanwo et al., 2012). Like many legumes, African yam bean contains protease inhibitors, these compounds can interfere with the activity of digestive enzymes, affecting protein digestion and potentially reducing the absorption of amino acids (Ene-Obong et al., 2002). Lectins are another class of antinutrients found in African yam beans. These proteins have the potential to bind to carbohydrates, affecting the absorption of nutrients and causing digestive issues in some individuals (Ugwuona & Aba, 2009). Phytic acid, or phytate, is present in African yam beans and can form complexes with minerals, reducing their bioavailability. High levels of phytic acid may hinder the absorption of essential minerals such as calcium, magnesium, and zinc (Oluwole et al., 2015). Oxalates are compounds that bind with minerals, forming insoluble salts. While African yam bean contains oxalates, the levels are generally lower compared to some other legumes. Still, excessive oxalate intake may pose a risk for individuals prone to kidney stone formation (Oloyede et al., 2015).

It is important to note that while antinutrients can impact nutrient absorption, they are also associated with some health benefits, such as antioxidant properties and potential anticancer effects. Several foods processing techniques, including seed dehulling, soaking and cooking, have been seen to considerably decrease the levels of certain anti-nutritional chemicals in African Yam Bean (Nwinuka et al., 1997).

2.3 Functional Properties of Seeds

The water absorption capacity of seeds is a crucial parameter influencing various aspects of their functionality and nutritional attributes. Water absorption is integral to seed germination, a vital stage in the plant life cycle. During germination, seeds imbibe water, triggering metabolic processes and facilitating the transition from dormancy to active growth

(Bewley, 1997). Research on seeds such as beans has explored their water absorption characteristics in the context of food processing and product development. For instance, the water absorption index (WAI) and water holding capacity (WHC) are commonly employed metrics to quantify the ability of seeds to take up and retain water. These indices provide valuable insights into the hydration behavior of seeds, influencing factors like texture, cooking characteristics, and overall quality in food applications (Giami, 1996). The water absorption capacity of seeds is intricately linked to their composition, including the presence of storage compounds such as starches, proteins, and fibers. Studies have demonstrated that the water absorption properties of seeds can be modified through processing techniques, impacting the functional attributes of seed-based products. For example, alterations in soaking conditions or the application of heat can influence the hydration kinetics and water absorption behavior of seeds (Falade et al., 2016). Beyond culinary considerations, understanding the water absorption capacity of seeds holds significance in the agricultural and environmental domains. Seed hydration not only initiates germination but also plays a role in seedling establishment and resilience to environmental stressors such as drought (Kigel & Galili, 1995).

Understanding the oil absorption capacity of seeds is pivotal in both the food and industrial sectors, impacting the formulation of various products. Oil absorption capacity is a key functional property, that influences the texture, flavor, and overall quality of foods (Mukherjee & Kakati, 2008). Additionally, it plays a crucial role in the extraction of oils for industrial purposes. In the realm of food science, seeds such as those from oilseeds have been extensively studied for their oil absorption behavior. Studies on oilseed crops, including sunflower seeds and soybeans, have highlighted the impact of processing methods on their oil absorption properties. For instance, heat treatments and mechanical processing can alter the structure of seeds, influencing their oil absorption characteristics (Mukherjee & Kakati, 2008; Jafari et al., 2009).Oil absorption capacity is not only relevant in food processing but also in the context of oilseed crops as a renewable source for industrial oil production. Variations in the oil absorption behavior of different seed varieties and the impact of processing techniques on oil extraction efficiency are crucial considerations for optimizing industrial processes (Ciftci et al., 2005). Furthermore, the oil absorption capacity of seeds is intertwined with their nutritional profile, as seeds are often rich sources of lipids and other bioactive compounds. Research in this area extends to understanding how the oil absorption properties of seeds contribute to the overall health benefits of the derived oils and their potential applications in functional foods (Liu et al., 2015).

2.4 Methods of determination of antinutrients in seeds

Research on the determination of antinutrients in seeds involves various analytical methods to assess their presence and concentration. Common antinutrients include phytates, tannins, lectins, and protease inhibitors (Smith et al., 2010). Classical methods, such as spectrophotometry, gravimetry, and titration, have been traditionally employed for their quantification (Jones, 2005). In recent years, chromatographic techniques, particularly high-performance liquid chromatography (HPLC) and gas chromatography (GC), have gained popularity due to their precision and sensitivity (White et al, 2018). These methods allow for the specific identification and quantification of individual antinutrients, enhancing analytical accuracy.

Advancements in spectroscopy, such as infrared spectroscopy (IR) and nuclear magnetic resonance (NMR), offer non-destructive alternatives for antinutrient analysis, providing insights into molecular structures and facilitating rapid screening (Johnson et al., 2019).Moreover, molecular biology techniques, like polymerase chain reaction (PCR), are increasingly applied to detect genes related to antinutrient content, offering a molecular-level understanding of seed composition (Robinson & Patel, 2021). While each method has its strengths and limitations, a combination of analytical techniques is often employed to obtain comprehensive data on antinutrient profiles in seeds (Lee & Garcia, 2022). Further research is needed to refine existing methods and explore emerging technologies for a more nuanced understanding of seed antinutrients.

Research on the determination of tannins, saponins, and phytates in African yam beans has been explored through various analytical methods to assess their concentration and nutritional impact. Tannins were commonly determined using methods such as spectrophotometry (Jones, 2010). This approach allows for the quantification of tannins in African yam bean seeds, providing insights into their potential effects on nutrient absorption.

Saponins, another group of antinutrients, have been analysed using both traditional methods like gravimetry and more advanced techniques such as high-performance liquid chromatography (HPLC) (Smith & Brown, 2015). These methods enable the precise identification and quantification of saponins in African yam beans, contributing to a better understanding of their nutritional implications.

Phytates, which can affect mineral bioavailability, have been studied using various methods, including spectrophotometry and ion chromatography (White et al., 2018). These analyses provide valuable information on the levels of phytates in African yam bean seeds and their potential impact on mineral absorption.

In summary, the determination of tannins, saponins, and phytates in African yam beans involves a combination of traditional and modern analytical methods, shedding light on the nutritional composition and antinutrient content of this important legume. Further research is crucial to refine these methods and explore additional technologies for a comprehensive understanding of the bioactive compounds in the African yam bean.

3. Aims of the Thesis

African yam bean is an underutilized legume that has nutritional potential as other known legumes like cowpea. African yam bean, however, has constraints including the presence of antinutrients and its longer cooking time, which have contributed to the decline in the use of the crop. Previous studies have indicated that these antinutrients can be reduced by soaking and fermentation. This study thus aimed to assess the effect of soaking and the ratio of seed to water during cooking on the antinutrient contents in the African yam bean.

The objectives also includes optimizing the cooking time and the amount of water needed to cook African yam bean and assessing the impact of soaking and cooking on the functional properties of African yam bean.

4. Method

The seeds of African yam bean (figure 7) used in this study were collected from a private farm called Jibril Enterprise in 2023, in the Ashanti Region of Ghana, dealers in all kinds of African plants seeds and agricultural products. Since Registered in 2018, Jibril enterprise has been proud to serve more than 40 countries in the world.

Figure 7: African yam bean seeds (Jibril farms, 2023)

4.1 Processing of Seeds

The fresh seeds were thoroughly cleaned, and any foreign materials, broken and immature seeds were removed. 20g of the sample was weighed and cooked in 5x[1] water, the optimum cooking time was observed for the unsoaked seeds. Another 20g of seeds were weighed and soaked overnight, the soak water was then decanted after the end of the soaking period. The

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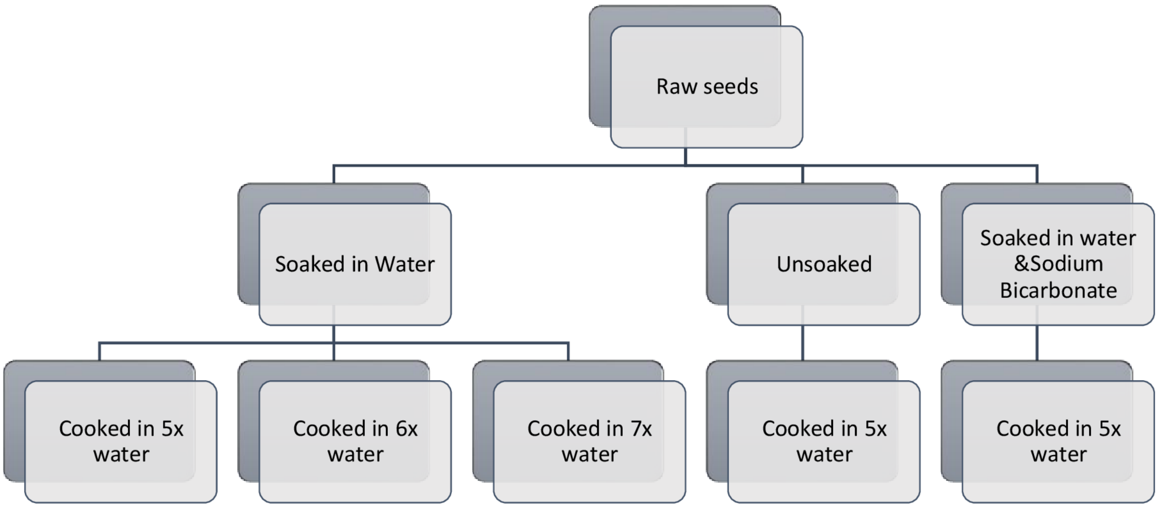
[1] 5x = five times

seeds were then soaked, and treatments were performed by cooking in 5x water, 6x water, and 7x water accordingly on a cooker at 200°C for their pre-determined cooking times. Another treatment was performed where the seeds were soaked in water containing sodium bicarbonate before cooking in 5x water. The seeds were then blended into a paste using a kitchen blender for about two minutes.



4.2 Chemicals/Equipment

- HCl (VWR International S.A.S, France)
- MeOH (Carl Roth GmbH co.KG, Germany)
- Vanillin (Merck spol sro, Czech Republic)
- Tannic acid (Sigma-aldrich co, Germany)
- Ethanol (VWR International S.A.S, France)
- H_2SO_4 (VWR International S.A.S, France)
- Diosgenin (Sigma-Aldrich co, China)
- Ammonium iron (III) sulfate dodecahydrate (Merck KGaA, Germany)
- 2'2' bipyridine (Merck spol sro, Czech Republic)
- Thioglycolic acid (Merck spol sro, Czech Republic)
- Phytic acid (Sigma-Aldrich co, Switzerland)
- Oil (Albert Ceska Republika, sro)
- Spectrophotometer (UV-1900i, Shimadzu corporation)

- Centrifuge (MPW med. Instruments)
- Water bath (Memmert)

4.3 Tannin analysis

Tannin was analysed using the Vanillin-HCl method as described by Onyango et al., 2005, Yadav et al., 2021 and Kheto et al., 2023 with slight modifications.

Firstly, a standard curve was prepared by adding 1g tannic acid to 100ml acidified methanol and this stock solution was used at various dilutions in the concentrations 0mg/ml, 1mg/ml, 2.5mg/ml, 5mg/ml, 10mg/ml, 25mg/ml, and 50mg/ml to determine the concentrations and from this, the standard curve was plotted in the spectrophotometer at a wavelength of 500nm. These dilutions were however treated in the same way the samples were treated. The samples were treated by taking 1g of the blended sample and combined with 10 ml acidified methanol (1 ml concentrated hydrochloric acid/100 ml methanol). The mixture was then kept overnight and centrifuged at 5000rpm for 20 minutes. 1ml of the supernatant was transferred into a test tube and combined with 5ml vanillin hydrochloric reagent (Vanillin-hydrochloric acid reagent was prepared by mixing equal portions of vanillin solution (4g vanillin/100 ml methanol) and acidified methanol (8 ml concentrated hydrochloric acid/100 ml methanol).
This mixture was then incubated for 20 minutes in the dark and the absorbance was measured using a UV–Vis Spectrophotometer at 500 nm against the Vanillin-HCl reagent as blank.

4.4 Saponin Analysis

Saponin was analysed using the diosgenin method as described by Kheto et al., 2023 with slight modifications. The standard curve was prepared by weighing 5mg of diosgenin and topping up with methanol to a volume of 10 ml (Stock solution), this solution was kept in a water bath for a few minutes as the diosgenin was difficult to dissolve. 0.8g of vanillin was also weighed and topped up to 10ml with ethanol. 72% sulphuric acid was prepared. Dilutions were prepared from the stock solution in the concentrations of 0mg/ml, 0.01mg/ml, 0.05mg/ml, 0.1mg/ml, 0.25mg/ml, and 0.5mg/ml. From these dilutions, 250µl was taken and combined with 250µl vanillin solution and 2.5ml 72% sulphuric acid. These solutions were then put in a water bath for 21 minutes with shaking at regular intervals of 7 minutes. After this, the absorbance of these known concentrations was taken at 448nm to plot the standard curve. sample extract was prepared by adding 10 ml of methanol to 1g of sample (blended seeds) and incubated overnight at ambient temperature. 0.5 ml sample extract was taken into a test tube, and 5 ml vanillin solution (800 mg vanillin into 10 ml of ethanol) followed by 5 ml of H_2SO_4 (72%) was immediately added. After that, the mixture was kept in a water bath for 21 minutes with shaking at regular intervals of 7 minutes. Absorbance was measured at 448 nm against a reagent blank(solvent).

4.5 Phytate Analysis

Phytate was determined using combining methods from Onyango et al., 2005, Yadav et al., 2021 and Kheto et al., 2023 with slight modifications.

A standard curve was prepared by preparing a stock solution by weighing 0.013g of phytate in 10ml 0.2mol HCl. 1 ml acidic ammonium iron (III) sulfate dodecahydrate (0.2 g $NH_4Fe(-SO_4)_2 \times 12H_2O$ in 100 ml 2 mol/l hydrochloric acids and made up to 1000 ml with distilled water) was added to the stock solution and boiled for 30mins, the solution was immediately cooled and 2 ml of 2’2’ bipyridine solution (10 g 2’2’ bipyridine and 10 ml thioglycolic acid in 1000 ml water) was added and the contents and mixed. Various dilutions were prepared using 0.2m HCl and left to stand for 20 minutes. After which the absorbance was read at 519 nm in the spectrophotometer and the standard curve was prepared.

The sample was extracted by adding 0.1 g sample to 10 ml 0.2 mol/l hydrochloric acid and shaken for 1 h before centrifuging at 5000 rpm for 15 min. The sample was then treated by adding 1 ml acidic ammonium iron (III) sulfate dodecahydrate (0.2 g $NH_4Fe(-SO_4)_2 \times 12H_2O$ in 100 ml 2 mol/l hydrochloric acid and made up to 1000 ml with distilled water) was added and boiled for 30 mins, the solution was immediately cooled and 2 ml of 2’2’ bipyridine solution (10 g 2’2’ bipyridine and 10 ml thioglycolic acid in 1000 ml water) was added and the contents mixed and left to stand for 20 minutes. The absorbance was then read at 519 nm.

4.6 Functional Properties

Water absorption capacity (WAC), oil absorption capacity (OAC), foaming capacity (FC), and emulsifying capacity (EC) of control and treated samples were determined according to the method described by Sharanagat et al. (2019) and Jogihalli, Singh, and Sharanagat (2017).

4.6.1 Water absorption capacity (WAC)

For water absorption capacity (WAC), 1 g of sample was mixed with 15 ml of distilled water (DW) and vortexed for 5 min. After that, the suspension was kept for 30 min, and centrifuged (5000 rpm; 30 min). Then, the supernatant was decanted, and WAC (g/g) was calculated by the equation:

$$WAC\ or\ OAC\ (\mathrm{g/g}) = \frac{Sample\ weight\ after\ ecentrifugation - Initial\ sample\ weight}{Initial\ sample\ weight} I$$

4.6.2 Oil absorption capacity (OAC)

To measure oil absorption capacity (OAC), 600 mg of sample was added to 10 ml of soybean oil. The suspension was vortexed for 5 min and left to stand for 30 min followed by centrifugation (5000rpm; 40 min). Then, the supernatant was discarded, and OAC (g/g) was calculated by equation:

$$WAC\ or\ OAC\ (\mathrm{g/g}) = \frac{Sample\ weight\ after\ ecentrifugation - Initial\ sample\ weight}{Initial\ sample\ weight} I$$

4.6.3 Water solubility index (WSI)

The water solubility index (WSI) of the samples was determined according to the method of Jhonsy et al. (2022) with slight modifications. In brief, 0.25 g of sample and 10 ml of DW were taken in a centrifuged tube. Then, the suspension was vortexed for few minutes and kept in a water bath (85 °C) for 30 min. After that, the suspension was immediately cooled and centrifuged for 20 min (5000 rpm) to collect the supernatant. Finally, the supernatant was transferred in Petri-dishes and kept at 105 °C for 3 hr. The WSI of the samples was calculated as g per 100 g using equation:

$$WSI\ \left(\frac{\mathrm{g}}{100}\mathrm{g}\right) = \frac{Final\ weight\ of\ supernatant\ after\ drying\ (Ws)}{Initial\ sample\ weight\ (Wi)} \times 100$$

4.6.4 Foaming capacity (FC, %)

For foaming capacity (FC), 50 ml of DW was added to 1 g of the sample and shaken for 5 min. The contents were immediately shifted in a measuring cylinder and the foam volume was noted. The FC (%) was calculated by equation:

$$FC\ (\%) = \frac{Volume\ after\ shaking - Initial\ volume\ of\ suspention}{Initial\ volume\ of\ suspention} \times 100$$

4.6.5 Emulsifying capacity (EC, %)

Likewise, emulsifying capacity (EC) was estimated by taking 50 mg of sample, 5 ml of DW, and 5 ml of soybean oil into a centrifuge tube. Then, the suspension was vortexed (5 min) and centrifugation was performed (1100 g; 5 min). "After that, the suspension was carefully transferred into a measuring cylinder, and the emulsion layer and total volume were noted."

$$EC\ (\%) = \frac{Emulsion\ volume}{Total\ volume} \times 100$$

4.6.6 Statistical analysis

All determinants were done in triplicates and subjected to statistical analysis of variance (ANOVA) using SPSS version 29. 0. 2. 0 (20) to determine if the results are significant. Turkeys' Least significance difference test (LSD) was further used to find out which specific groups' means (compared with each other) are different. Significance variation was accepted at p = .05.

5. RESULTS

5.1 Effect of Soaking and Volume of Water on the Cooking Time

Some significant limitations associated with the use of African yam bean seeds are their inherent difficulty in hydration, the challenging nature of seed coat removal, and the prolonged duration of boiling needed. The usual method used in household processing to improve the softness of seeds for faster cooking involves the application of soaking solutions that include inorganic salt. The findings shown in Table 3 indicate that the time required for cooking the unsoaked seeds was 100 minutes. The pre-soaked seeds exhibited a decrease in cooking time, resulting in a 60% reduction. However, the cooking time of the seeds remained unaffected by an increase in the amount of water utilized during the cooking process. Immersing the seeds in water containing sodium bicarbonate resulted in a 70% decrease in the cooking time of the seeds.

Table 3: The impact of pre-soaking and water volume on the duration of cooking

Soaking Time (HR)	Volume of water	Cooking Time (mins)	Percent reduction (%)
0	5x	100	0
24	5x	40	60
24	6x	40	60
24	7x	40	60
24 + sodium bicarbonate	5x	30	70

5.2. The Impact of Water Soaking and Volume on Antinutrient Factors

The study examined the antinutrient components of Saponin, Tannin, and Phytate. As outlined in the aforementioned protocol, the extraction of tannin was conducted, followed by the measurement of absorbance using a spectrophotometer. Subsequently, a standard curve was generated by using tannic acid (TA) and then expressed as mg/g. Similarly, the extraction of phytate was conducted, and a standard curve was generated by using a phytic acid solution consisting of a combination of 100 ml of hydrochloric acid (0.2 N) and 130 mg of phytic acid sodium salt hydrate. Saponin was also extracted, absorbance was read, and the standard curve was prepared using diosgenin and expressed as mg diosgenin/g. Experiments were performed as three independent tests, each performed in triplicate, and the results were expressed as a mean value.

The concentrations of Tannin exhibited statistically significant differences at a significance level of 0.05. The unsoaked seeds that underwent cooking had the greatest content of Tannin, measuring 3.6 ± 0.26. A statistically significant difference was seen between the first treatment (unsoaked and cooked in 5x DW) and the other treatments, as determined by the Turkeys LSD test. The levels of Tannin exhibited a declining relationship with the quantity of water used in the cooking process of the seeds. The data presented in Table 4 indicates that the seeds soaked for 24 hours and cooked in 5x water experienced a 17% decrease in Tannin concentration. Similarly, the seeds soaked in DW for 24 hours and cooked in 6x water exhibited a 19% decrease in Tannin concentration. Finally, the seeds that were immersed in DW for 24 hours and then cooked in 7x water exhibited a reduction of 22% in Tannin content. However, the seeds that were submerged in water containing Sodium Bicarbonate and then treated in 5x water showed a reduction of 14% in Tannin concentration. The magnitude of this reduction was somewhat less in comparison to the percentage decline seen in seeds that underwent a 24-hour soaking period and were then cooked in 5x water. It is however important to note that there was not much difference between seeds that were soaked and cooked in 6x water and 7x water.

Table 4:The impact of pre-soaking and water volume on the concentration of tannins (mg/g)

Treatments	**Tannin Concentration**	**Percentage reduction (%)**
Unsoaked, cooked in 5x DW	3.6 ± 0.26	0
Soaked, 24hr, cooked in 5x DW	3.0 ± 0.06	17
Soaked, 24hr, cooked in 6x DW	2.9 ± 0.03	19
Soaked, 25hr, Cooked in 7x DW	2.8 ± 0.05	22
Soaked in DW+ sodium bicarbonate, 24hr, cooked in 5x DW	3.1 ± 0.38	14

Mean ± standard deviation of three replications, means are significantly different ($p<0.05$)

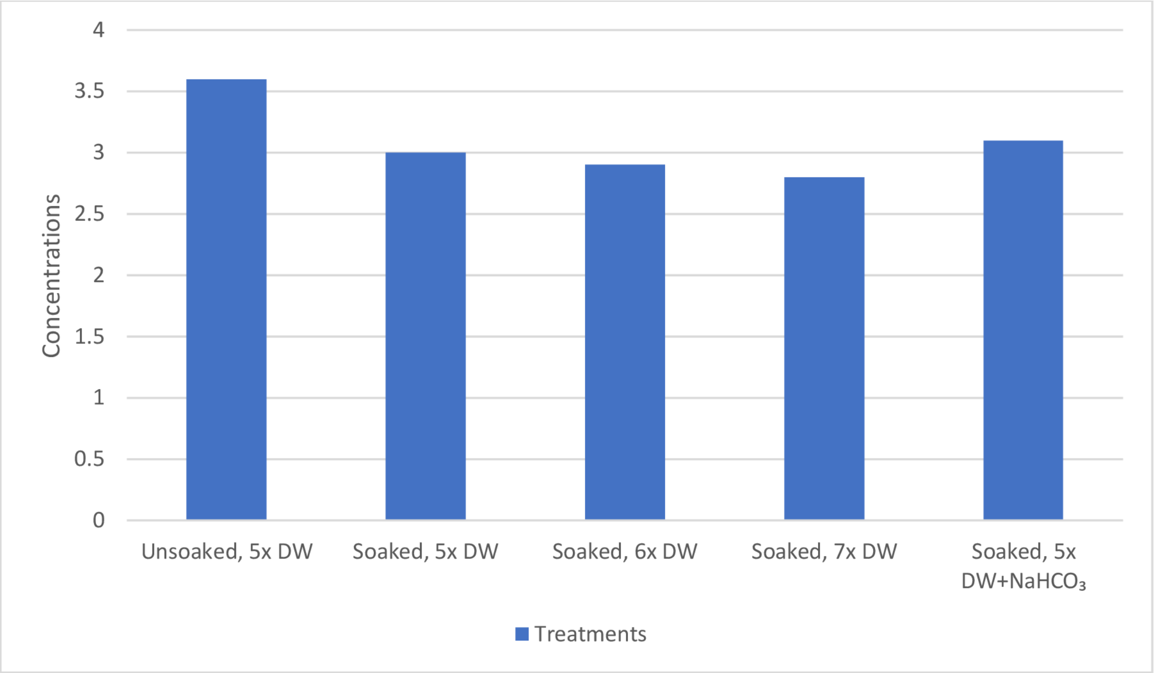


Figure 9: Tannin Graph; various treatments against their concentrations.

The concentrations of Saponin exhibited statistically significant differences at a significance level of 0.05. The unsoaked seeds that were cooked had the greatest content of Saponin at 2.0 ± 0.12, whereas the samples soaked in sodium bicarbonate had the lowest concentration at 1.2 ± 0.07. There was also a significant difference between the unsoaked seeds and the rest of the treatments. The concentrations significantly decreased as the volume of water used to cook the seeds increased. It is interesting to note that, seeds that were soaked in water containing sodium bicarbonate had the lowest tannin concentration. The percentage reductions as shown in Table 5, shows that the seeds that were soaked for 24 hours and cooked in 5x water had a 20% reduction in saponin concentration, seeds cooked in DW for 24 hours and cooked in 6x water had a 25% reduction, seeds soaked in DW for 24 hours and cooked in 7x water had a 30% reduction. When immersed in a solution of DW containing Sodium Bicarbonate and cooked, the seeds had a 40% decrease.

Table 5: Effects of pre-soaking and volume of water on Saponin Concentration(mg/g)

Treatments	**Saponin Concentration**	**Percentage reduction (%)**
Unsoaked, cooked in 5x DW	2.0 ± 0.12	0
Soaked, 24hr, cooked in 5x DW	1.6 ±0.05	20
Soaked, 24hr, cooked in 6x DW	1.5 ± 0.02	25
Soaked, 25hr, cooked in 7x DW	1.4 ± 0.01	30
Soaked in DW+ sodium bicarbonate, 24hr, cooked in 5 DW	1.2 ± 0.07	40

Mean ± standard deviation of three replications, means are significantly different ($p<0.05$).

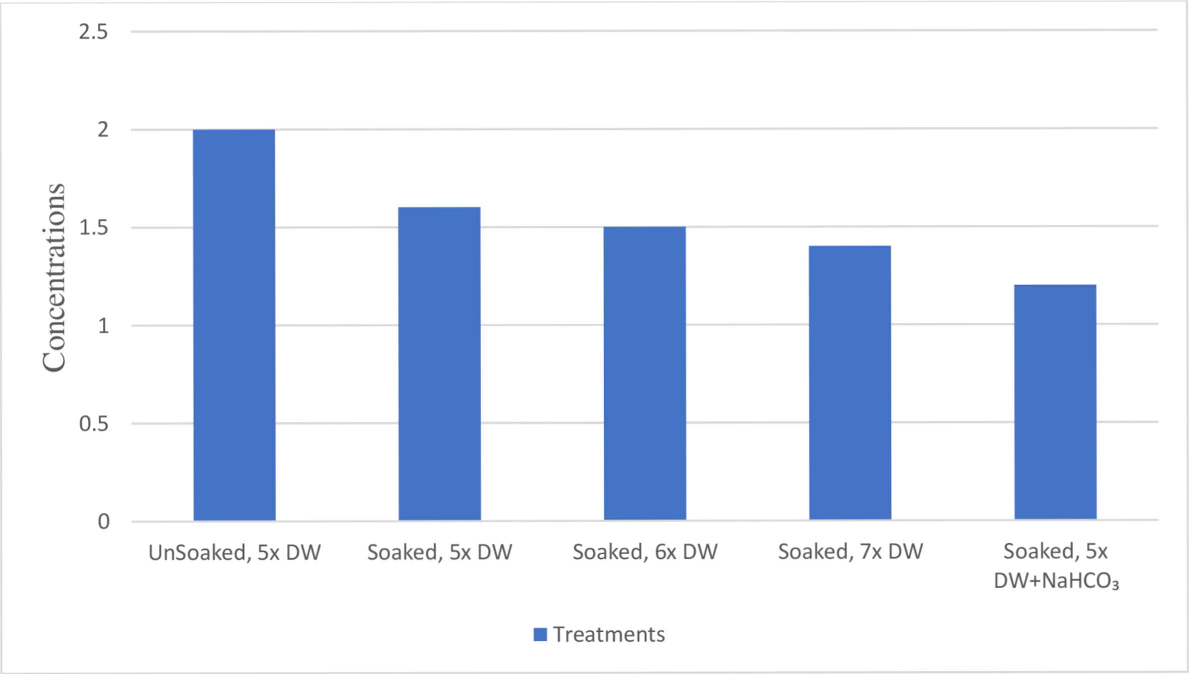


Figure 10: Saponin Graph, various treatments against their concentrations

The concentrations of phytate exhibited significant differences at a significance level of 0.05. Additionally, a statistically significant difference was seen between the groups. The concentrations exhibited a notable drop with an increase in the amount of water used for seed cooking. The data presented in Table 6 illustrates the percentage reductions in Saponin concentration for different treatment conditions. Specifically, seeds soaked for 24 hours and cooked in 5x water exhibited a 13% reduction in Saponin concentration. Seeds cooked in DW for 24 hours and cooked in 6x water demonstrated a 19% reduction, while seeds soaked in DW for 24 hours and cooked in 7x water exhibited a 22% reduction. The seeds that were immersed in a solution of DW containing Sodium Bicarbonate and then cooked exhibited a decrease of 27%, surpassing the reduction seen in seeds soaked in DW and cooked in 5x water.

Table 6: Effects of pre-soaking and volume of water on Phytate concentration

Treatments	**Phytate Concentration**	**Percentage reduction (%)**
Unsoaked, cooked in 5x DW	3.7 ± 0.02	0
Soaked, 24hr, cooked in 5x DW	3.2 ±0.08	13
Soaked, 24hr, cooked in 6x DW	3.0 ± 0.03	19
Soaked, 25hr, cooked in 7x DW	2.9 ± 0.05	22
Soaked in DW+Sodium Bicarbonate, 24hr, cooked in 5x DW	2.7 ± 0.05	27

Mean ± standard deviation of three replications, means are significantly different ($p<0.05$).

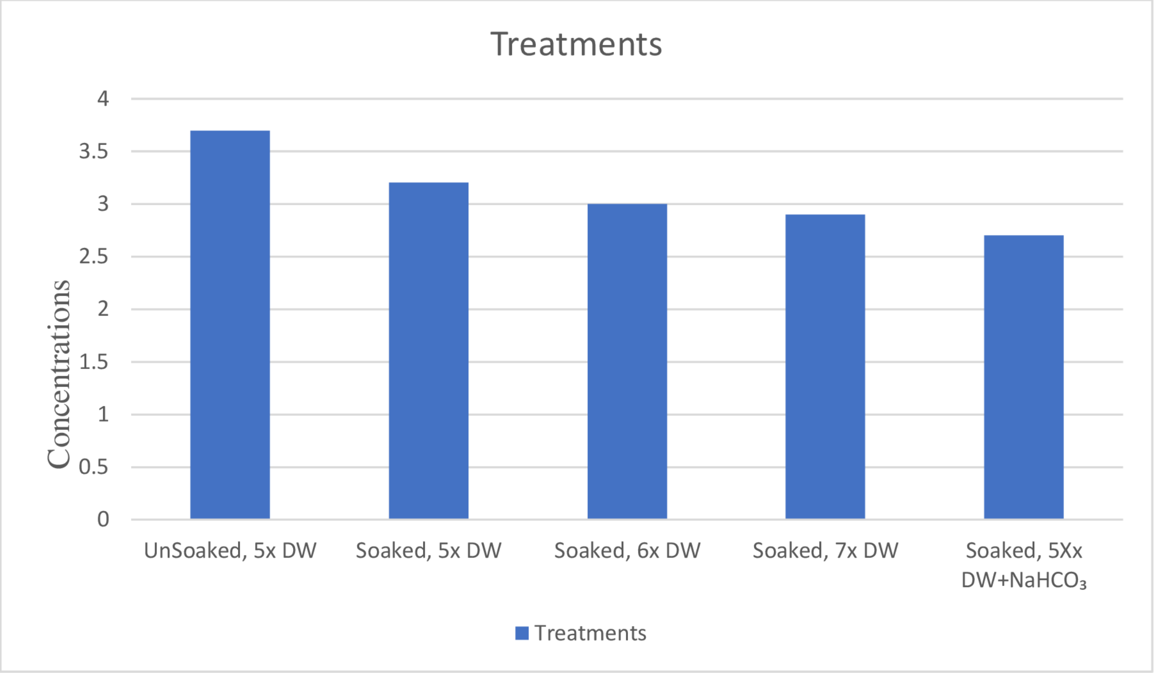


Figure 11: Phytate Graph, various treatments against their concentrations

5.3 Effect of Soaking and Volume of Water Functional Properties

From Table 7, WAC shows a slight increase in values as the volume of water used to cook the seeds increased, there was however a decrease in seeds soaked with water containing sodium bicarbonate. OAC values increased slightly as the volume of water used to cook the seeds also increased, however, there was no difference between the seeds that were not soaked and cooked in 5x water and the seeds that were soaked with Sodium Bicarbonate and cooked with 5x water.

There was no difference in the emulsifying capacity of the seeds as the treatments differed, the results show just a slight increase with the seeds that were soaked in Sodium bicarbonate and cooked in 5x water.

The foaming capacity also showed no difference in values in the various treatments, there was however a significant increase in the foaming capacity of seeds soaked in water containing sodium bicarbonate, this was observed while cooking.

No significant difference was observed between the treatments for WSI except for the seeds that were soaked in Sodium Bicarbonate where there was a decrease in WSI for the seeds.

Table 7: Effects of pre-soaking and volume of water on the functional properties

TREATMENTS	WAC	OAC	EC	FC	WSI
Unsoaked, cooked in 5x DW	1.4 ± 0.05	1.2 ± 0.05	0.49 ± 0.00	0.1 ± 0.00	0.4 ± 0.00
Soaked, 24hr, cooked in 5x DW	1.5 ± 0.05	1.3 ± 0.11	0.49 ± 0.00	0.1 ± 0.00	0.4 ± 0.00
Soaked, 24hr, cooked in 6x DW	1.5 ± 0.05	1.4 ± 0.05	0.50 ± 0.00	0.1 ± 0.00	0.4 ± 0.00
Soaked, 24hr, cooked in 7x DW	1.6 ± 0.00	1.5 ± 0.05	0.49 ± 0.00	0.1 ± 0.00	0.4 ± 0.00
Soaked in DW+Sodium Bicarbonate, 24hr, cooked in 5x DW	1.3 ± 0.05	1.2 ±0.05	0.51 ± 0.00	0.5 ± 0.05	0.2 ± 0.02

Mean ± standard deviation of three replications, means are significantly different ($p<0.05$).

(Were, WAC-Water absorption Capacity, OAC-Oil absorption Capacity, EC- Emulsifying Capacity, FC-Foaming Capacity, WSI-Water Solubility Index)

6. Discussion

AYB is known for its longer cooking time which requires more energy consumption. The results showed that, the pre-soaking of the seeds decreased the cooking time of AYB. Similar findings were reported by (Coskumer & Karabana, 2003), (Urga et al. 2006), and (Bhokre & Joshi 2015) for chickpea, grass pea, and cowpea seeds that were pre-soaked before cooking. The percentage reductions were not affected by the increase in the volume of water used to cook the seeds. The greater reduction in cooking time was observed in seeds soaked in sodium bicarbonate, this could be explained by the fact that the presence of sodium salt increases the softening rate (Silva et al.1981). The reduction in cooking time after soaking might be because the soaking solution helped to soften the Testa and dissolved the binding gum between the Testa and the cotyledon, thereby decreasing the cooking process, (Ghavidel et al., 2012) It might also be due to the process of hydration, which softens the seed coat and allows water to penetrate the seed more easily (Ghavidel et al., 2012). This hydration process helps to break down complex carbohydrates and proteins, making them more digestible and thus reducing the time required for cooking (Kokubun et al., 2015). In addition to the hydration process, soaking seeds before cooking also activates enzymes present in the seeds, which helps to break down antinutrients such as phytic acid and enzyme inhibitors (Hernández-Ledesma et al., 2014). This breakdown of antinutrients enhances the bioavailability of nutrients like vitamins and minerals, further aiding in the digestion and absorption of nutrients during cooking (Nakitto et al., 2018). Additionally, soaking can help to soften tough outer layers of seeds, making them more palatable and easier to chew (Singh et al., 2019). Given the high cost of energy in developing nations such as Ghana, the decrease in cooking time achieved by pre-soaking AYB in sodium bicarbonate is significant.

African yam beans contain antinutrients such as phytates, tannin, and saponin, which may inhibit the absorption and use of vital elements, lowering their bioavailability and nutritional value and contribute to bitterness and astringency (Kataria & Gandhi,1988), (Nwosu, 2013). This study found a higher tannin concentration of 3.6 ± 0.26 mg/g, compared to earlier reports of 0.12 mg/g and 3.34 mg/g [(Anya & Ozung, 2018), (Ihemeje et al., 2018)]. However, AYB has been observed to have much greater tannin content (18.09 mg/g) and (38.80 mg/g) [(Adegboyega et al., 2019), (Ndidi et al., 2013)] especially in varieties with a darker seed coat. The lowest tannin content was found in seeds that were soaked and cooked in 7x water. Soaking seeds before cooking decreases the tannin content primarily due to the process of leaching, wherein water solubilizes and carries away the tannins present in the seeds (Araújo et al., 2016). From the results, it can be said that cooking seeds in more water helps the tannins because tannins are water-soluble polyphenolic compounds found in seeds. The tannins will disperse in the water when cooked, leading to a reduction in their concentration and bitterness. When seeds are soaked in water, the tannins dissolve into the soaking water, resulting in a reduction of the concentration in their seeds.This reduction in tannin content during soaking is beneficial for several reasons. First, it improves the taste of the cooked seeds by reducing bitterness and astringency. Second, it enhances the digestibility of the seeds by removing compounds that can inhibit the absorption of nutrients. (Dias et al., 2019). As a result, this African yam bean variety, when soaked and cooked in 7x water, at the lowest tannin level, may aid in the development of AYB cultivars with lower tannin content.

Soaking seeds before cooking decreases the phytate content primarily due to the process of hydrolysis, wherein water breaks down the phytate molecules into simpler forms (Nakitto et al., 2018). Phytates are naturally occurring compounds found in seeds that can bind to minerals such as calcium, magnesium, iron, and zinc, forming insoluble complexes that are poorly absorbed by the body. This research found a greater phytate level (3.7 ± 0.02) than previously reported throughout AYB accessions (0.002-0.72) [Adegboyega et al., 2019; Ndidi et al., 2013]. The high phytate concentration in this study might be attributed to genetic variations in the examined accession as well as external factors, both of which are known to impact crop nutrient quality (Fanzo et al., 2019). When seeds are soaked in water, the phytates undergo hydrolysis, resulting in the release of bound minerals and a reduction in phytate concentration. This reduction in phytate content during soaking is beneficial as, it improves the bioavailability of minerals present in the seeds, making them more accessible for absorption by the body.it also reduces the risk of mineral deficiencies that can occur due to poor mineral absorption caused by phytates. (Hemalatha et al., 2017). Phytate, which has been recognized as a contributing factor to longer cooking times in legumes (Ihemeje et al., 2018), was shown to be minimal in seeds soaked in sodium bicarbonate which also reflected in the time (thirty minutes) required to cook the seeds that were soaked and cooked in 5x DW and sodium bicarbonate, as result, this form of treatment might be used to generate cultivars that need less cooking time.

Saponins are naturally occurring compounds found in seeds that can impact bitterness and foaming properties. They are composed of a diverse collection of triterpene or steroidal glycosides and mostly forms covalent bonds with glycosyl groups at locations C-3 and C-17 (via C-28) (Nath et al., 2022). Furthermore, an elevated level of saponins (exceeding 1.2% of the human diet) has the potential to generate harmful substances, reduce the rate of vitamin absorption, and disrupt the integrity of the cell membrane (Nath et al., 2022; Sharma et al., 2023). The highest Saponin content in this study was 2.0 ± 0.12 and the lowest Saponin content was 1.2± 0.07 with seeds soaked with sodium bicarbonate. The reduction in saponin content in treated samples might be correlated with the breakdown of glycosidic bonds, the process of leaching, wherein water solubilizes and carries away the saponins present in the seeds (Abeysekara et al., 2017). The results show that soaking AYB seeds in sodium bicarbonate has the lowest Saponin content as well as the highest foaming property, high foaming properties are advantageous in applications where aeration and volume are desired, such as in baking to create light and fluffy textures in cakes or bread (Smith et al., 2010). Examples of products that benefit from high foaming properties include whipped toppings, meringues, soufflés, and certain beverages (Hoseney, 1994), soaking AYB seeds in sodium bicarbonate can be of great aid in production of such products.

The oil absorption capacity measurement is crucial in food formulations because of its impact on organoleptic qualities, such as mouthfeel and flavour, which are influenced by the quantity of oil absorbed in samples (Turan et al., 2015). Based on the results, in Table 7, OAC increased slightly as the volume of water used to cook the seeds increased, the highest was observed in seeds soaked in 7x water. Protein degradation and denaturation may cause hydrophobic groups to link with oil's hydrocarbon chains, raising OAC in samples. Ingredients with high oil absorption capacity are beneficial in applications where oil retention is desired, such as in the production of fried foods, where they can help retain the oil and prevent excessive oil absorption, resulting in a crispier texture (Bettger & Champagne, 2007).

The water absorption/solubility index (WAI) estimates the quantity of water absorbed by starch and may be used as a gelatinization index (Ding et al., 2003). The water solubility index (WSI) is a test that indicates the quantity of soluble solids and is often used to detect starch deterioration. It is also a metric for assessing starch conversion rates during processing, as well as the quantity of polysaccharides released from starch granules (Jogihalli et al., 2017). In this study there was no increase in the WSI as the volume of water used to cook the samples increased, there was however a reduction in samples soaked in Sodium bicarbonate, it is therefore not an advisable way to treat samples during processing. Monitoring WAI is crucial for food safety, especially in products where water absorption influences microbial growth or shelf stability (Rahman et al., 2019), Food scientists utilize WAI data to formulate new food products or optimize existing ones, aiming for desirable textures and sensory characteristics (Kim et al., 2017).

7. Conclusion

In this study, the concentrations of antinutrients in the African yam bean seeds when subjected to different treatments were determined. The results revealed that soaking before and cooking the seeds in a sufficient amount of water (6x to/7x) reduces the presence of antinutrients in AYB. The findings show that soaking African yam beans in water before cooking in a ratio of about 1:7 of water is an optimized way of leaching out a good amount of antinutrients in the seeds and soaking the seeds in sodium bicarbonate helps to efficiently reduce the cooking time of the seeds. The good functional characteristics of the AYB seed could be used in food formulation like bread, sponge cakes, muffins, etc. The study also successfully identified germplasm with low antinutrient content, compared with other studies that have documented the presence of antinutrient in AYB A molecular technique for identifying the assessed trait's genetic architecture should be studied for future research.

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