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Alleviation of Hard-to-cook Phenomenon in Legumes: Effects of Hydrothermal Processing Techniques on Two Species of *Vigna subterranean*

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Abstract The hard-to-cook nature of *Vigna subterranean* constitutes an hindrance to its utilisation. Two species of a hard-to-cook legume *Vigna subterranean* were subjected to hydrothermal processing after soaking. This study is aimed at investigating the effects of soaking followed by hydrothermal processing on the cooking times. The seeds of two species of *Vigna subterranean* (the cream coloured specie and the mottled coloured specie,) were processed by four different hydrothermal techniques before and after aqueous soaking to varying hydration levels. Soaking of the seeds to varying hydration levels before processing by hydrothermal techniques induced decrease in the cooking times. Highest percentage reduction of 66.24% was recorded when the seed of the cream coloured variety was boiled at elevated pressure.

Keywords: *Vigna subterranean, hard-to-cook, hydrothermal techniques, cooking times*

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1. Introduction

In many nations of the world and especially in developing countries, legumes, otherwise known as beans or pulses, are regarded as a group of important plants because they are good and cheap sources of nutritionally important nutrients such as protein. Apart from protein, legumes contain varying concentrations of mineral elements, carbohydrates and vitamins [1]. With the exception of Glycine max and *Arachea hypogea* that contain reasonable quantity of oil, legumes are not good sources of oil [2,3]. Legumes are many in varieties and the consumption patterns vary depending on the regions of the world. Of all classes of plants legumes have been reported to be a good and practical alternative to animal protein [4]. However, a major hindrance to the utilisation of legumes is the presence of antinutritional/antiphysiological components which interfere with the absorption of nutrients and hence prevents their efficient utilisation. These antinutrtional components include protease inhibitor, heamaglutinin, phytic acid, saponin, tannin etc [5,6]. Moreover, the phenomenon of hard-to-cook nature of many legumes constitutes another hindrance to their utilisation.

One of the great advantages of legumes is that they can be stored in the home thereby making a significant contribution to the family diets during dry season or in the periods of food shortage. Hardening of testa can occur during storage. This hardening increases the time required to soften the legume seeds during cooking. Certain conditions such as long period of storage and high storage temperature can enhance increase in cooking time [7]. Hardness is influence by the chemical interaction of the components of phytin with other phosphorus compounds, calcium, magnesium, tannin, pectin and by the chemical and physical properties of the starches [8]. Legumes contain much carbohydrates mostly in the form of starch. The starch granule is composed of a mixture of amylose and amylopectin [9]. High amylose content delays starch gelatinization and affects normal cooking properties [10].

Many processing methods have been employed to solve the problem of prolonged cooking in legumes. It has been reported that hardening of the testa during storage can be controlled by steaming for ten minutes at atmospheric pressure or by steaming under pressure for two minutes followed by drying before storage. This can improve water absorption and softening of the seeds on soaking and cooking [8]. Addition of chemical compounds such as sodium bicarbonate, sugar and ash has been used to soften legume seeds during cooking [11,12]. In Southern Nigeria, tenderiser such as trona is often added to the cooking water to hasten softening thereby reducing duration of cooking [11].

Vigna subterranean, commonly called Bambara groundnut after the Bambara people of the Upper Niger of Africa, is an underutilised legume in South West Nigeria. *Vigna subterranean* has been reported to be a good source of protein [13]. In this study, two species of *V. subterranean* --- cream coloured and mottled coloured varieties have been selected for processing. Efforts have been made to reduce the cooking time using hydrothermal processing techniques. It is hoped that reduction in cooking time will encourage further utilisation thereby strengthen dietary diversity and healthy eating habits.

2. Materials and Methods

2.1. Samples and Preparation

Dried seeds of two species of *Vigna subtteranean* locally called *bambara* --- the cream coloured specie, CC (Figure 1a) and the mottled coloured specie, MC (Figure 1b), were obtained from Irawo in Atisbo Local Government Area of Oyo State, Nigeria. Broken and immatured seeds as well as other extraneous materials such as stones and stalks were removed. The seeds were then stored in labelled plastic containers at ambient temperature prior to subsequent processing. Seeds of each of the two legumes were processed by the following methods: soaking, atmospheric boiling, atmospheric steaming, pressure boiling and pressure steaming.

Figure 1a. *Vigna subtterranean (*Bambara groundnut, Cream coloured specie*)*

Figure 1b. *Vigna subtterranean* (Bambara groundnut, mottled coloured specie)

2.2. Soaking and Determination of Soaking Time

Soaking and determination of hydration rate of the legume were carried out [14,15]. The legume sample (500 g) was cleaned and soaked in 2500 cm^3 of distilled water in a glass beaker at ambient temperature (23-28°C) for up to 24 h. Water absorption (increase in moisture) of the legume during soaking was measured hourly for the initial 0-6 h and every two hours. The soaked legume was blotted with a woolen hand towel at appointed time to remove excess water before weighing and returning into soaking water. Moisture content of soaked legume was calculated. Furthermore, the water absorption curve was plotted to show the kinetic increase of the moisture content with time. The plateau phase of water absorption curve was defined as 100% hydration level. Soaking time of the legume with desired hydration level was calculated through polynomial equation of respective water absorption curves.

For the subsequent boiling and steaming experiments, the legume was pre-soaked to the desired hydration levels of 10, 25, 50, 75 and 100% by controlling soaking time. The soaked legume was then boiled or steamed by the methods below: the raw sample without soaking (0 % hydration level) served as the control.

2.3. Boiling at Atmospheric Pressure (BAP)

The boiling of the legume sample was done using a domestic cooker. Pre-soaked legume (500 g) with varying hydration levels was boiled separately in distilled water [15,16]. Determination of cooking time was performed by tactile method [17]. After boiling treatment the seeds were drained and both the cooking water and the drained seeds were cooled in plastic containers to ambient temperature (23-28) °C.

2.4. Boiling at Elevated Pressure (BEP)

Boiling at elevated pressure was done using a pressure cooker (Binatone PC-5001) at about 80±8 KPa. Pre-soaked legume (500 g) with varying hydration levels was put each in distilled water in a glass flask covered with aluminium foil. The flask containing the legume was quickly brought to boiling on a hot plate. The legume sample with boiling water was placed into pre-heated pressure cooker with boiling water and the lid was locked. The cooking time was counted from when steam began to spurt out from pressure regulator on the lid. Cooking time was determined by tactile method [17]. When the legume has been cooked to the desired cooking time, the pressure cooker was then removed from the hot plate and the pressure released. The boiled legume sample was cooled to ambient temperature.

2.5. Steaming at Atmospheric Pressure (SAP)

Steaming and determination of steaming time were carried out at normal atmospheric pressure using steam cooker. The pre-soaked legume sample (500 g by weight) with varying hydration levels was placed each on a tray in the steam cooker covered with lid and were steamed over boiling water. Steaming time was determined by tactile method [17]. After the steaming process, the cooked seeds were was cooled to ambient temperature.

2.6. Steaming at Elevated Pressure (SEP)

Steaming at elevated pressure was performed using a pressure cooker (Binatone PC-5001) at about 80±8 KPa. Pre-soaked sample (500 g by weight) of varying hydration levels was placed each on a tray in a pressure cooker and steamed over boiling water under elevated pressure (80±8 KPa). Steamed seeds were placed in plastic containers.

2.7. Statistical Analysis

The results of the experiments were expressed as mean ± standard deviation of three replicates. The data were subjected to one-way analysis of variance using the SPSS statistical analysis software version 15.0 [18]. Duncan Multiple Range Test was used to separate the means and the significance differences were determined at $p<0.05$.

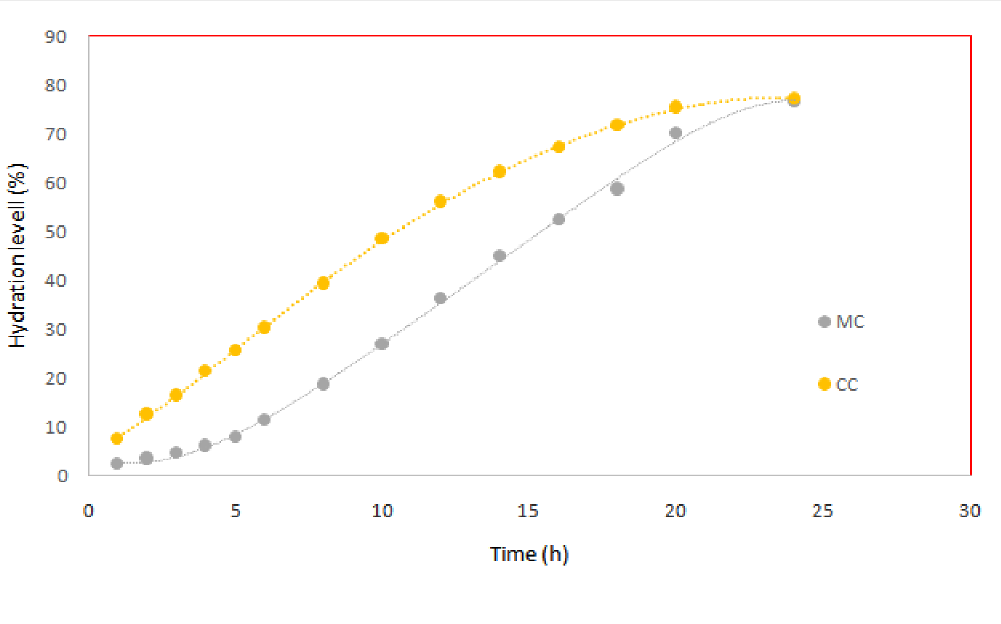

Figure 2. Water absorption curves for two species of *Vigna subterranean*

3. Results and Discussion

3.1. Soaking Effect on Hydration Levels of the Legume Seeds

The water absorption curves for each of the two species of *V. subterranean* are shown in Figure 2. The curves give indication of the hydration levels attainable with time for each of the varieties. In spite of the fact that the two varieties are cultivars of similar specie, there was variation in their water absorption patterns. Hydration levels of 10% and 25% were attained at 1 hour 42 minutes and 4 hours 30 minutes, respectively for MC and at 5 hours 18 minutes and 10 hours for CC. Also, it took 18 hours 30 minutes for MC to attain the hydration level of 75% while it took 24 hours for CC to get to 75% hydration level. These results show that MC absorbed water faster than CC. The more rapid rate of water absorption in all probability explains the reason for the relatively shorter cooking times recorded for this legume (MC). Thus, the rate of water absorption influences the cooking time: the faster the rate of absorption of water, the shorter the cooking time.

3.2. Effects of Soaking Followed by Hydrothermal Processing on Cooking Times of the Legume Samples

The combined effect of soaking at varying hydration levels followed by hydrothermal processing on cooking times of the two legumes are presented in Table 1 and Table 2. The corresponding volumes of water used for each cooking operation are also recorded. As recorded in Table 1 and Table 2, there were significant differences ($p<0.05$) in the cooking times when the raw sample of each of the two species of *V. subterranean* were cooked using different hydrothermal processing methods. For the raw cream coloured variety (CC), the duration for cooking ranged from 110 minutes for boiling at elevated pressure to 237 minutes for boiling at ambient pressure (Table 1). However, the mottled coloured variety (MC) took a shorter period of 80 minutes when cooked at elevated pressure of 80±8 KPa (Table 2). As shown in Table 1 and Table 2, hydration of the two varieties to 10% did not induce any significant changes ($p<0.05$) in the duration of the cooking. The cooking times of the two seeds at hydration levels of 0% and 10% were similar because hydration of the seeds to 10% was not sufficient to cause the seeds to absorb enough water required for softening prior to cooking. The percentage reduction in the cooking time of CC at 25% hydration level ranged from 6.33% for BAP to 55.70% for BEP while at 50, 75 and 100% hydration levels the percentage reduction ranged from 6.33 - 57.81, 35.86 - 63.71 and 40.93 - 66.24%, respectively. The highest percentage reduction of 64.52 was observed at 100% hydration level when the mottled coloured variety was processed by boiling at elevated pressure: steaming at the same pressure caused percentage reduction of 50.35%. The cooking times of the mottled coloured variety at varying hydration levels were different from that of the cream coloured variety although they are cultivars of similar specie. It could be inferred that boiling of the two legume seeds at elevated pressure caused better reduction in the cooking time at varying levels than steaming; pressure boiling also saves energy too. In general, increase in hydration level was directly related to reduction in cooking time. Similarly, there was increase in the volume of water used to effect cooking as the hydration level of the seeds increased. The raw sample (0% hydration level) of cream coloured variety required 3850 cm^3 of water to effect cooking when the seed was boiled at ambient pressure. At 100% hydration level, the seed only required 1100 cm^3 of water (representing 71.43% reduction in volume) to effect boiling. Addition of tenderisers such as sodium carbonate and trona to cooking water has been used to shorten cooking time [13]. There is paucity of information on the comprehensive effects of the use of these tenderisers on human physiology. In view of the general trend away from the use of chemical additives in food processing, application of soaking followed by hydrothermal processing of the legume seeds to shorten cooking times could be considered desirable [19,20]. Similarly, the mottled coloured variety required more water (2670 cm^3) when it was processed by boiling at ambient pressure. Cooking of the seed at 100% hydration level only required 900 cm^3 water. For each of the two legumes, the quantity of water used for cooking at elevated pressure was less than that of boiling and steaming at ambient pressure.

Table 1. Effect of soaking of *Vigna subterraean* --- cream coloured variety, at varying hydration levels followed by hydrothermal processing on cooking times

	Volume of H_2o used (cm^3)				Cooking times (min)			
Hydration levels	BAP	SAP	BEP	SEP	BAP	SAP	BEP	SEP
0%	3850c ± 70.68	4850d± 14.21 {20.62}*	1400a± 0.00 { 63.64}	1670b ± 7.07 {56.62}	237c ± 2.00	312d ± 6.00 {24.04}*	110a ± 2.00 {53.59}	144b ± 1.00 {39.24}
10%	3800c ±113.14 {1.30}	4850d±35.35 {20.62}*	1400a ±0.00 {63.64}	1650b ±70.71 {57.14}	237c ±3.21 { 0.00}	300d ±4.00 {21.00 }*	110a ±3.51 {53.59}	144b ±0.00 {39.24}
25%	3050c ±21.21 {20.78}	3900d ±0.00 {1.28}*	1400a ±49.49 {63.64}	1600b ±17.67 {58.44}	222c ±1.41 {6.33}	293d ±0.71 {19.11}*	105a ±0.00 {55.70}	137b ±0.00 {42.19}
50%	3000c ±0.00 {22.08}	3830d ±45.96 {0.52}*	1350a ±0.00 {64.94}	1590b ±0.00 {58.70}	222c ±1.41 {6.33}	280d ±0.00 {15.36}*	100a ±0.00 { 57.81}	125b ±2.83 {47.26}
75%	2700c ±60.10 {29.87}	3450d ±10.61 {10.39}	1300a ±56.57 {66.23}	1510b ±21.21 {60.78}	115c ±2.12 {51.48}	152d ±1.41 {35.86}	86a ±1.41 { 63.71}	107b ±2.12 {54.85}
100%	2650b ±35.35 {31.17}	3400c ±70.71 {11.69}	1100a ±35.35 {71.43}	1270a ±49.50 { 67.01}	110c ±2.12 {53.59}	140d ±1.41 {40.93}	80a ±0.00 {66.24}	92b ±1.41 {61.18}

Values above are means ± standard deviation (n=3); means with different letters on the same row are significant (p<0.05).
Values in parenthesis represent percentage decrease. Values with * represent percentage increase.
BAP=boiling at atmospheric pressure; SAP=steaming at atmospheric pressure; BEP=boiling at elevated pressure; SEP=steaming at elevated pressure.

Table 2. Effect of soaking of *Vigna subterraean* --- mottled coloured variety, at varying hydration levels followed by hydrothermal processing on cooking times

	Volume of H_2o used (cm^3)				Cooking times (min)			
Hydration levels	BAP	SAP	BEP	SEP	BAP	SAP	BEP	SEP
0%	2670c ± 20.00	3370d± 20.00 {20.77}*	1400a± 20.00 {47.57}	1670b ± 5.00 {37.45}	155c ± 1.00	206d ± 1.00 {24.76}*	80a ± 0.00 {48.39}	105b ± 1.00 {32.26}
10%	2670c ±28.28 {0.00}	3300d ±56.56 {20.77}*	1400a ±0.00 {47.57}	1600b ±70.10 {40.01}	155c ±2.82 {0.00 }	180d ±2.82 {13.89}*	77a ±1.42 {50.32 }	105b ±1.41 {32.26}
25%	2220c ±14.14 {16.85}	3200d ±56.56 {16.56}*	1200a ±14.14 {55.06}	1430b ±17.67 {46.44}	130c ±0.00 {16.12}	172d ±1.41 {9.88}*	65a ±2.12 {58.06}	85b ±0.00 {45.16}
50%	2100b ±0.00 {21.35}	2700c ±0.00 {1.11}*	1000a ±70.71 {62.55}	1180a ±56.57 {55.81}	121c ±2.12 {21.94}	157d ±2.12 {1.27}*	60a ±1.41 {61.29}	75b ±2.82 {51.61}
75%	1550b±49.50 {41.95}	2630c ±21.21 {1.50}	900a ±49.50 {66.29}	1050a ±35.36 {60.67}	106c ±2.83 {31.61}	135d ±3.54 {12.90}	55a ±0.00 {64.52}	63b ±2.12 {59.35}
100%	1550c ±50.00 {41.95}	1800d±60.00 {32.58}	900a±0.00 {66.29}	1050b±50.00 {60.67}	106c ±3.25 {31.61}	135d±3.00 {12.90}	55a± 0.00 {64.52}	63b±1.00 {50.35}

Values above are means ± standard deviation (n=3); means with different letters on the same row are significant (p<0.05).
Values in parenthesis represent percentage decrease. Values with * represent percentage increase.
BAP=boiling at atmospheric pressure; SAP=steaming at atmospheric pressure; BEP=boiling at elevated pressure; SEP=steaming at elevated pressure.

4. Conclusion

Prolonged thermal processing of these legume seeds at ambient condition is time consuming, expensive and potentially damaging. It is therefore important that the duration of cooking time be kept minimal. Although soaking is not an absolute method, hydration of the legume seeds to varying levels prior to hydrothermal processing reduced cooking time. This is a desirable unit operation to solve the problem of prolonged cooking. Hydration of the legume seeds to 100% followed by pressure boiling has comparative advantage over other methods when consideration for cooking time becomes important. This is certainly better than the use of chemical tenderisers the safety levels of which are yet to be established. It is hoped that reduction in cooking time will encourage adaptation of these underutilised legumes and strengthen dietary diversity and healthy eating habits.

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