Food Science and Quality Management
ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online)
Vol.40, 2015

Impact of Storage Conditions on the Physical Properties and Cooking Characteristics of Two Bean Varieties Grown in Kenya

Valentine Wacu* Elizabeth Namaemba Anselimo Makokha Daniel Njoroge Peter Kinyanjui Daniel Sila
Department of Food Science and Technology, Faculty of Agriculture, Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000-00200 Nairobi, Kenya
*E-mail of the corresponding author valwacu@gmail.com

Abstract
Common beans are highly nutritious and widely consumed in Kenya. Storage of common beans under adverse conditions of high temperature and high humidity renders them susceptible to the hard-to-cook (HTC) defect. This results in increased cooking time, fuel and water use which has a negative effect on acceptability and utilization of beans. The objective of this study was to determine effects of storage temperature and relative humidity on development of the HTC defect in Rose coco and Red Kidney bean varieties. Bean samples were obtained from Kenya Agricultural and Livestock Research Organization (K ALRO) - Thika. The beans were stored at varying temperature (25ºC, 35˚ C and 45˚ C) and relative humidity (RH=75% and 83%) combinations. Apart from beans stored at 25ºC/75%, samples from each treatment condition were sampled after every two months and analyzed for physical properties. Soaking pretreatments in deionized water, sodium carbonate and calcium chloride solutions were carried out to determine their effect on the cooking time. There was a significant increase in conductivity and leached solutes paralleled by decreasing hydration and swelling coefficients with increasing storage time under all the storage conditions. Characteristic dimensions and one hundred seed weight were not significantly different among the bean varieties under various storage conditions. Moisture uptake reduced by 19% for Rose coco and 23% for Red kidney under 35˚C/83% storage whereas 45˚C/75% had a 29% reduction for Rose coco and 39% reduction for Red kidney over the 6 months storage period. Cooking time increased for all the bean varieties with increasing storage time, the most pronounced increase (100%) being observed at 45˚C and 75% RH. Across the 6 months storage period, Na_2CO_3 soaking pretreatment reduced the cooking time by 75% for Rose coco and 70% for Red kidney in comparison to beans cooked without prior soaking. Based on the results of this study, it was concluded that storage under high temperature and relative humidity conditions accelerated the development of the HTC defect in beans resulting in changes in physical and cooking properties.
Keywords: hard-to-cook, storage, physical properties, cooking quality

1. Introduction

Common beans are food legumes of the genus *Phaseolus*. Beans grow from sea level up to 3000 m altitude and are cultivated either in monoculture, associations or in rotations (Broughton *et al.,* 2003). Grain legumes, especially common bean, are a staple food for people in many parts of the world (Galiotou-Panayotou *et al.*, 2008). They supply a significant amount of protein for a great part of the world population, especially in poor countries where the consumption of animal protein is relatively low (Batista *et al.,* 2010). Furthermore, their high content of protein, carbohydrates, fib res, some minerals and vitamins make beans an excellent nutrient source. Beans are generally stored at ambient temperature for varying periods of time before consumption. The storage period varies from several months up to several years (Kaur & Singh 2007). Storage of beans at high temperatures (45ºC) and high relative humidity (83%) may result in cumulative increases in cooking time, loss of cooking quality and reduced water uptake during cooking (Yousif & Deeth, 2003). This is characteristic of the hard to cook problem in beans. The mechanism of the hard-to-cook phenomenon is very complex and involves changes in the intracellular, cell wall and middle lamella polysaccharides and other components (Galiotou-Panayotou, *et al* 2008). Majority of research presented in literature attests that the main mechanisms involve the interaction of phytate and divalent cations with pectin (Galiotou-Panayotou, *et al* 2008). This theory has been reported to be based on the phytase-phytate-pectin hypothesis whose explanation was provided by Mattson.,1946. According to this hypothesis, pectin cements the plant cells together. Divalent ions like calcium and magnesium can crosslink the carboxyl groups of soluble pectin, transforming them into insoluble calcium and magnesium pectates. On the contrary, phytate has six strong phosphate groups and these prevail over the weak carboxyl groups of pectin and chelates preferentially with the divalent cations. Therefore under these conditions, pectin remains soluble and hence the legume seeds are easy to cook. However when phytate is hydrolysed by phytase, the chelating power disappears and allows cross linking of pectic substances via calcium and magnesium bridges. Calcium and magnesium pectates formed do not dissolve readily on heating, thus restricting cell separation, inhibiting water uptake and thus resulting in hard-to-cook (HTC) defect in beans and legumes in general (Mattson., 1946). Therefore conditions (temperature, RH) that accelerate the activity of phytase lead to development of the HTC defect (Ockenden *et al.,* 1997). HTC phenomenon is of great importance nutritionally and subsequently has commercial consequences (Jones & Boulter, 1983)

Beans with this defect are characterized by extended cooking times for cotyledon softening, are less acceptable to the consumer due to loss of flavor and colour, and are of lower nutritive value (Reyes and Paredes., 1993). The objective of this study was to determine effects of storage temperature and relative humidity on development of the HTC defect in common beans and the subsequent physical and cooking property changes.

2. Materials and Methods

2.1 Bean sampling and storage conditions

The bean varieties, Red kidney (GLP 24) and Rose Coco (GLP 2), freshly harvested were acquired from Kenya Agricultural and Livestock Research Organization (K ALRO) Thika, Kenya. These were subjected to the different storage temperature of 25ºC, 35°C and 45°C and relative humidity of 75% and 83%. These conditions were achieved by using storage incubators pre-conditioned to the desired temperature. A control sample of freshly harvested beans was stored at -20 °C for each variety after the equilibration at 25˚ C and 75% RH for two weeks. The respective relative humidity was achieved using concentrated salt solutions of potassium chloride (83 % relative humidity) and sodium chloride (75% relative humidity). 25˚C and 75% RH was the control storage condition while 35˚C 83% RH and 45˚C 75% RH were the accelerated conditions of storage. Sampling was carried out at 0, 2, 4 and 6 months.

2.2 Sample pretreatment and cooking

Beans were soaked for 16 h at a ratio of 1:5 (w/v) (bean weight: soaking solution) in de-ionized water, 0.1 M calcium chloride and 0.025M sodium carbonate. The calcium chloride concentration was according to the modified method of Clemente et al., 1998, while the 0.025M sodium carbonate was due to the retention of natural color of the beans unlike higher concentrations which gave a more dark color. These were then cooked at a temperature of 96.5^0 C in a water bath (water bath shaker model: SHA-C, No: 10706004, IKA Labortechnik, Japan). Beans were considered to be fully cooked when the cotyledon could disintegrate on pressing between the thumb and the fore-fingers (Kinyanjui *et al*., 2015). The cooking profile of the beans was followed as a function of time in all the cases. The number of cooked seeds was recorded for every sampling step. Consequently, cooking profiles were obtained by plotting the percentage number of cooked seeds against cooking time.

2.3 Physical properties

The physical tests were carried out after each sampling as explained below:

2.3.1 Characteristic dime ns ion of seeds

This was carried out using a Vernier caliper (Mitutoyo, Tokyo, Japan) where length and width of each variety was assessed using a representative sample of ten seeds from each variety.

2.3.2 One hundred seed weight

The weight of a hundred seeds (g) was determined using a weighing balance (Libror AEG220 Shimadzu, Tokyo, Japan) in triplicate and averaged for each of the two bean varieties documented.

2.3.3 True Seed density

True seed density was calculated by recording the weight of twenty seeds in triplicate for each bean variety. The weight o f a 100 ml volumetric flask was recorded and so was its weight with water filled up to the mark. Each of the twenty seeds was then placed into the volumetric flask and water added up to the mark and the weight recorded. The seed volume (V) was estimated by dividing the mass of the displaced water (g) by the density of water (g/cm3). Seed density was calculated from the values obtained for weight (g) of twenty seeds and volume (cm3).

$$True\ seed\ density = \frac{\text{weight of 20 seeds in (g)}}{\text{volume of 20 seeds (cm3)}} \quad (1)$$

2.3.4 Bulk Seed density

Bulk density (BD) was determined using the method of Wang & K insella (1976). An empty graduated measuring cylinder (250 ml) was weighed. Seed material of common bean was placed in the graduated measuring cylinder and packed by gentle tapping of the cylinder on a bench top. This weight was recorded (g). Bulk density (g/cm3) was calculated as:

$$\text{Bulk Density} = \frac{\text{(cylinder and sample weights)} - \text{(cylinder weight)}}{\text{volume of cylinder}} \quad (2)$$

2.3.5 Seed Porosity

This is the property of the grain which depends on its bulk and true densities. Mohsenin., 1980 presents the formula for its calculation as shown below:

$$P = 100\left(1 - \frac{BD}{TSD}\right) \quad (3)$$

Where BD is bulk density (g/cm^3) and TSD is seed density (g/cm^3)

2.3.6 Hydration coefficient

Twenty seeds of each variety were weighed in triplicate and soaked in deionized water at 25°C for 16 h at a ratio of 1:5 (w/v) (bean weight to water). After soaking, the beans were cut into half along the fissure. The testa and cotyledon were separated and free water was removed using a blotting paper. The seeds were reweighed.

$$Hydration\ coefficient = \frac{Weight\ of\ beans\ after\ soaking}{Weight\ of\ beans\ before\ soaking} \times 100 \qquad (4)$$

2.3.7 Swelling coefficient

Twenty seeds of each variety were weighed in triplicate and soaked in deionized water at 25°C for 16 h at a ratio of 1:5 (w/v) (bean weight to water) The volume of raw bean seeds before and after soaking in deionized water was determined by water volume displaced in a graduated cylinder and expressed as the swelling coefficient.

$$Swelling\ coefficient = \frac{Volume\ of\ beans\ after\ soaking}{Volume\ of\ beans\ before\ soaking} \times 100 \qquad (5)$$

2.3.8 Electrolytes and solutes le aching

Twenty seeds of each variety were soaked in deionized water for 16 h at 25°C. The soaking water was then collected and leached electrolytes were quantified by assessing conductivity with a digital conductivity meter (Sisabata model SC – 179, Tokyo, Japan). The solutes leached from beans were quantified by evaporating the soaking water by drying in a hot air oven at 105°C, followed by cooling in a desiccator and weighing. Results were expressed as mg/g dry weight of beans.

2.3.9 Grain colour

A Colorimeter (Minolta chromameter- CR-200b) was used to take colour measurements. The instrument assesses color in Hunter (L* a*b*) form; Hunter L-values, (whiteness/lightness, Hunter-a value (redness) and Hunter-b value (yellowness). The instrument was first calibrated using standard white plate with transparent paper placed over the standard plate. After calibration, colour measurements were taken at random in triplicates.

2.4. Moisture uptake

20 seeds of each variety were weighed, placed in perforated bags and cooked in triplicate. After 30 minutes interval, they were removed and re-weighed to determine the weight gain which reflects the moisture uptake during cooking.

3. Results and Discussion

3.1 Effect of storage conditions on physical properties

The physical properties of the beans samples are presented in Tables 1 - 4. Substantial differences occurred in physical characteristics of both bean varieties stored at different conditions. According to Table 1 there was no significant difference in length, width and seed weight after 6 month storage. Similarly, Table 2 where there was no significant difference in bulk and seed density during storage at different conditions. Clear differences were observed in colour changes, electrical conductivity, leached solutes and hydration and swelling coefficients. Hydration and swelling coefficients reflect the capacity to imbibe water in a reasonable amount of time (Nasar-Abbas *et al*., 2008). For both bean varieties, hydration and swelling coefficients decreased as is indicated in Table 3. After 16 h soaking at 25^0C, the hydration coefficients were lower in samples stored under accelerated storage conditions of temperature and humidity compared to those stored at ambient temperature and humidity conditions. Similarly, the swelling coefficient reduced as it mainly depends on the amount of water absorbed. Electrical conductivity and amount of leached solutes increased with increased storage temperature and humidity for Rose coco, while Red Kidney was inconsistent. After 16 h soaking the loss of solids and electrolytes from beans at accelerated storage conditions of temperature (35˚ C and 45˚ C) and relative humidity (75% and 83% RH) was high as compared to that of the control samples (freshly harvested bean samples stored at -20 °C after the equilibration at 25˚ C and 75% RH for two weeks) and this was an indication of development of the HTC defect. Evidently, a link between hydration and swelling coefficients can be drawn from this. The low hydration and swelling coefficients after storage at high temperatures can be due to chemical changes in the testa making it harder and less permeable to water thus preventing water from reaching the cotyledons (Liu *et al.,* 1992). Jones and Boulter (1983) stated that leached solids may affect hydration rate of beans in two ways. On one hand, the leached solids in the soaking water may increase the concentration of the solution which in turn affects water absorption rate. On the other hand, solute leakage may reduce water affinity and water holding capacity as is stipulated by osmotic principles. The colour readings determined in terms of Hunter -L values (whiteness), Hunter-a values (redness) and Hunter-b values (yellowness) are tabulated in Table 4. Hunter- L values for both varieties decreased indicating darkening which is associated with hardening of the bean. Hunter- a values increased indicating an increase in redness. This was in agreement with the findings of Uebersax and Bedford (1980) who observed that Hunter L values decreased with increased relative humidity, storage time and temperature. Similarly, Hellevang and Henson (2000) found that Hunter a and b values increased with increased relative humidity, temperature and storage time. This decrease in color quality is associated with hardening.

Table 1: Dimensional characteristics of Rosecoco and Red kidney bean varieties.

Storage conditions		True seed density		Bulk seed density		Porosity	
(°C/% RH)	Time (months)	Rose coco	Red kidney	Rose coco	Red kidney	Rose coco	Red kidney
25/75	0	1.23 ± 0.01	1.25 ± 0.01	0.77 ± 0.01	0.82 ± 0.01	37.4± 0.01	34.4 ± 0.01
45/75	0	1.23 ± 0.01	1.25 ± 0.01	0.77 ± 0.01	0.82 ± 0.01	40.7 ± 0.01	36.9 ± 0.01
	2	1.25 ± 0.01	1.28 ± 0.04	0.77 ± 0.01	0.82 ± 0.003	40.7 ± 0.01	36.9 ± 0.01
	4	1.2 4 ± 0.01	1.26 ± 0.01	0.81 ± 0.01	0.82 ± 0.004	32.5 ± 0.01	36.9 ± 0.01
	6	1.23 ± 0.02	1.27 ± 0.02	0.81 ± 0.01	0.82 ± 0.01	32.5 ± 0.01	36.9 ± 0.01
35/83	0	1.23 ± 0.01	1.25 ± 0.01	0.77 ± 0.01	0.82 ± 0.01	37.3 ± 0.01	34.4 ± 0.01
	2	1.22 ± 0.01	1.19 ±0.01	0.77 ± 0.004	0.80 ± 0.003	36.8 ± 0.01	32.7 ± 0.01
	4	1.23 ± 0.02	1.28 ± 0.04	0.78 ± 0.002	0.76 ± 0.01	35.0 ± 0.01	41.5 ± 0.01
	6	1.00 ± 0.01	1.03 ± 0.00	0.78 ± 0.01	0.79 ± 0.002	35.0 ± 0.01	43.5 ± 0.01

Values = Mean ± SD. Each value is a mean of 3 replicates. S.D (standard deviation) ($p \leq 0.05$)

Table 2: Density characteristics of Rosecoco and Red kidney bean varieties.

Storage conditions		True seed density		Bulk seed density		Porosity	
(°C/% RH)	Time (months)	Rose coco	Red kidney	Rose coco	Red kidney	Rose coco	Red kidney
25/75	0	1.23 ± 0.01	1.25 ± 0.01	0.77 ± 0.01	0.82 ± 0.01	37.4± 0.01	34.4 ± 0.01
45/75	0	1.23 ± 0.01	1.25 ± 0.01	0.77 ± 0.01	0.82 ± 0.01	40.7 ± 0.01	36.9 ± 0.01
	2	1.25 ± 0.01	1.28 ± 0.04	0.77 ± 0.01	0.82 ± 0.003	40.7 ± 0.01	36.9 ± 0.01
	4	1.2 4 ± 0.01	1.26 ± 0.01	0.81 ± 0.01	0.82 ± 0.004	32.5 ± 0.01	36.9 ± 0.01
	6	1.23 ± 0.02	1.27 ± 0.02	0.81 ± 0.01	0.82 ± 0.01	32.5 ± 0.01	36.9 ± 0.01
35/83	0	1.23 ± 0.01	1.25 ± 0.01	0.77 ± 0.01	0.82 ± 0.01	37.3 ± 0.01	34.4 ± 0.01
	2	1.22 ± 0.01	1.19 ±0.01	0.77 ± 0.004	0.80 ± 0.003	36.8 ± 0.01	32.7 ± 0.01
	4	1.23 ± 0.02	1.28 ± 0.04	0.78 ± 0.002	0.76 ± 0.01	35.0 ± 0.01	41.5 ± 0.01
	6	1.00 ± 0.01	1.03 ± 0.00	0.78 ± 0.01	0.79 ± 0.002	35.0 ± 0.01	43.5 ± 0.01

Values = Mean ± SD. Each value is a mean of 3 replicates. S.D (standard deviation) ($p \leq 0.05$)

Table 3: Soaking characteristics of Rose coco and Red kidney bean varieties.

Storage conditions		Hydration coefficient (%)		Swelling coefficient (%)		Conductivity (mmh/cm)		Leached solutes (%)	
(°C/% RH)	Time (mon)	Rose coco	Red kidney	Rose coco	Red kidney	Rose coco	Red kidney	Rose coco	Red kidney
25/75	0	211.3 ± 0.99	205.6 ± 0.7	267.8 ± 13.5	266.7 ± 14.4	1.8 ± 0.1	2.7 ± 0.4	0.03 ± 0.01	0.05 ± 0.01
45/75	0	211.3 ± 0.99	205.6 ± 0.7	267.8 ± 13.5	266.7 ± 14.4	1.8 ± 0.1	2.7 ± 0.4	0.03 ± 0.01	0.05 ± 0.01
	2	203.7 ± 2.7	201.9 ± 6.1	259.4 ± 4.4	242.4 ± 16.5	2.6 ± 0.4	4.1 ± 0.5	0.06 ± 0.01	0.09 ± 0.04
	4	196.6 ± 1.1	190.2 ± 0.4	252.2 ± 12.9	225.0 ± 7.1	3.4 ± 0.2	5.1 ± 0.4	0.09 ± 0.01	0.1 ± 0.01
	6	191.7 ± 1.4	184.9 ± 3.2	203.7 ± 12.8	224.4 ± 13.5	5.5 ± 0.8	7.5 ± 0.7	0.05 ± 0.02	0.07 ± 0.05
35/83	0	211.3 ± 0.99	205.6 ± 0.7	267.8 ± 13.5	266.7 ± 14.4	1.8 ± 0.1	2.7 ± 0.4	0.03 ± 0.01	0.05 ± 0.01
	2	211.8 ± 0.8	195.8 ± 0.9	256.7 ± 0.6	246.7 ± 5.8	2.9 ± 0.3	5.3 ± 0.2	0.09 ± 0.01	0.1 ± 0.04
	4	197.0 ±1.7	191. ± 7.2	234.4 ± 4.4	222.5 ± 3.5	4.2 ± 0.3	5.6 ± 0.5	0.1 ± 0.09	0.05 ± 0.04
	6	189.4 ± 0.2	188.3 ± 1.03	229.9 ± 10.8	219 ± 1.4	4.1 ± 0.5	6.8 ± 0.8	0.1 ± 0.01	0.1 ±0.02

Values = Mean ± SD. Each value is a mean of 3 replicates. S.D (standard deviation) ($p \leq 0.05$)

Table 4: Colour characteristics of Rosecoco and Red kidney bean varieties.

Storage conditions		Rose coco			Red kidney		
(°C/% RH)	Time (mon)	L	a	b	L	a	b
45/75	0	46.9 ± 2.4	11.8 ± 0.5	4.6 ± 1.1	43.8 ± 0.6	4.9 ± 0.6	1.8 ± 0.3
	2	45.9 ± 2.4	9.1 ± 0.3	3.9 ± 0.4	41.4 ± 1.7	3.9 ± 0.3	0.3 ± 0.2
	4	40.4 ± 2.7	11.2 ± 1.3	3.8 ± 2.5	41.8 ± 3.7	5.8 ± 0.5	0.8 ± 0.7
	6	27.9 ± 5.4	15.7 ± 1.0	12.3 ± 0.5	23.9 ±1.3	13.3 ± 2.2	4.2 ± 1.6
35/83	0	46.9 ± 2.4	11.8 ± 0.5	4.6 ± 1.1	43.8 ± 0.6	4.9 ± 0.6	1.2 ± 0.3
	2	48.2 ± 4.6	10.4 ± 2.4	4.2 ± 1.7	44.1 ± 0.4	4.7 ± 0.7	1.2 ± 0.1
	4	43.1 ± 2.7	10.7 ± 0.8	3.6 ± 0.6	40.2 ± 2.6	5.3 ± 1.4	1.1 ± 0.5
	6	37.4 ± 1.9	17.0 ± 2.4	13.4 ± 2.9	23.4 ± 3.8	8.3 ± 0.7	1.2 ± 0.3

Values = Mean ± SD. Each value is a mean of 3 replicates. S.D (standard deviation) ($p \leq 0.05$)

3.2 Effect of storage time on cooking properties

Beans at 0 storage time had shorter cooking times than beans stored for 2, 4 and 6 months at accelerated storage conditions. The cooking profile for 45°C/75% RH (Figure 1) and 35°C/83% RH (Figure 2) shows an increase in cooking time along the six month storage period in both bean varieties in comparison to cooking time at the start of the experiment. For Rose coco bean stored at 45°C/75% RH the cooking times were 120 min at 0 month, 150 min at 2 months, 180 min at 4 months and 240 min at 6 months. This translated into 100% increase in cooking time across the 6 month storage time. Similarly, there was a 100 % increase in cooking time for Red kidney beans stored at 45 °C/75%. For Rose coco bean stored at 35°C/83% RH, the cooking times were 120 min at 0 month, 150 min at 2 months, 180 min at 4 months and 210 min at 6 months. This was a 50% increase in cooking time. For Red kidney beans stored at 35°C/83% RH the cooking times were 150, 180, 210 and 240 after storage for 0, 2, 4 and 6 months respectively This was a 60% increase in cooking time This is an indication that increased storage time under the accelerated storage conditions(45°C /75% RH and 35°C/83% RH) plays a vital role in the hardening process of beans as is depicted by increase in cooking time. This is in line with Berrios *et al.,* (1999), Henteges *et al,* (1991), Morris (1963) and Muneta (1964) findings.

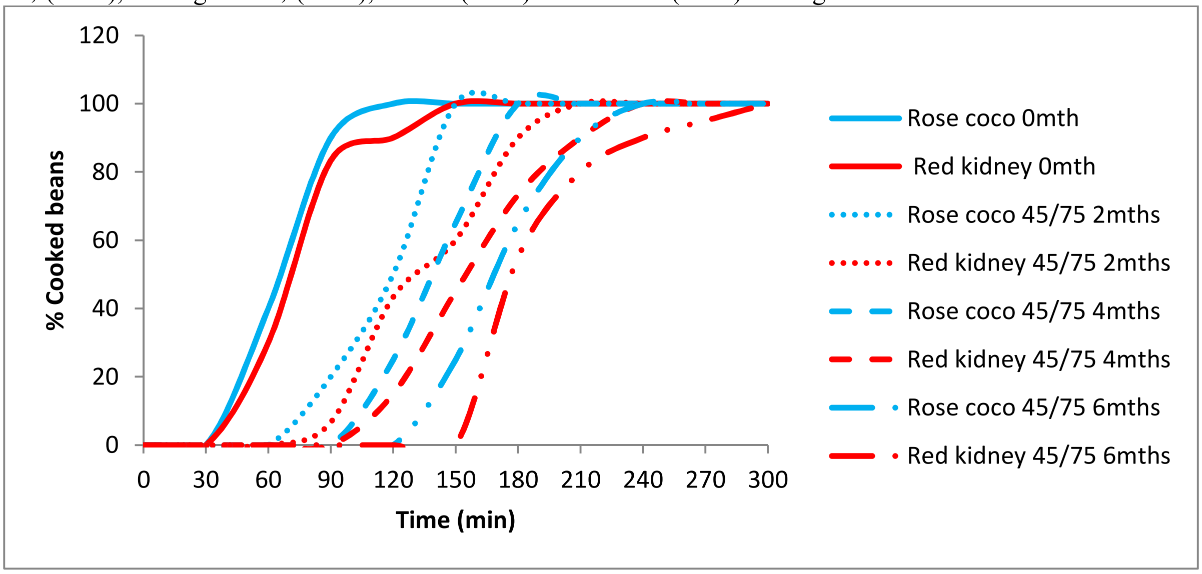

Figure 1: Cooking profiles for Rose coco and Red kidney beans at 45°C/ 75% RH during 0, 2, 4 and 6 months storage

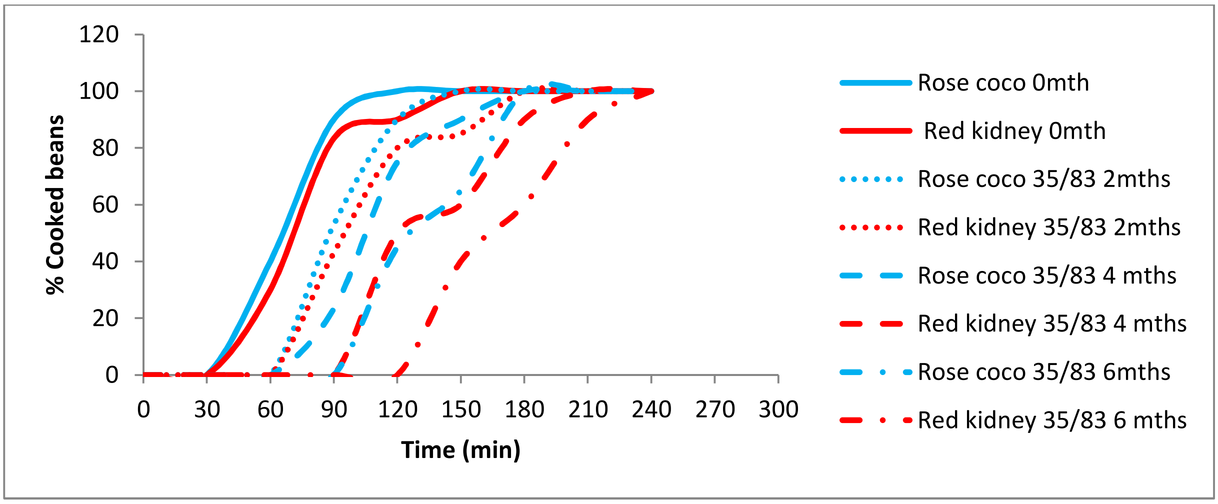

Figure 2: Cooking profile for Rose coco and Red kidney beans at 35^0C / 83% RH during 0, 2, 4 and 6 months storage

3.3 Effect of Relative Humidity on cooking properties

Storage of common beans in high relative humidity conditions (75% and 83%) led to development of the hard to cook defect (**Figure 3**). The 83% RH caused an increase in cooking time from 150 min at 75%RH to 180 min in Rose coco. Red kidney bean had an increase from 210 min at 75%RH to 240 min at 83% RH. This is in agreement with Kilmer *et al.,* (1994) who found that, high humidity (> 75%) results in the hard to cook (HTC) condition. Research by Ndung'u *et al.,* (2012) found that even a relative humidity of (60% - 80%) can lead to development of the HTC defect.

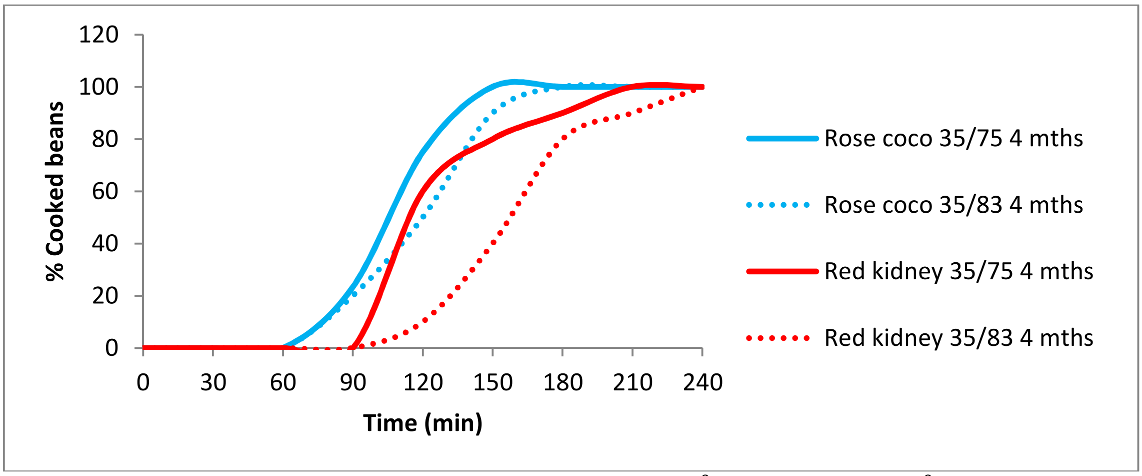

Figure 3: Cooking profile for Rose coco and Red kidney beans at 35^{0}C / 83% RH and 35^{0}C / 75% RH stored for 4 months.

3.4 Effect of temperature on cooking properties

Increase in storage temperature resulted to increased cooking time. This is as depicted in Figure 4 below. The increase in cooking time depicts that the beans have developed the HTC defect. Over the 6 months storage period, there was a 40 % increase in cooking time for Rose coco bean and a 33 % increase in cooking time for Red kidney bean from 25^0 C to 45^0 C. High temperature during storage result to deteriorative effects on common bean seed quality. Nasar-Abbas *et al*., 2008 states that the main form of deterioration is increased hardness of cotyledons or loss of ability to soften with cooking followed by deterioration of colour, texture and loss of nutritive value. Changes associated with HTC phenomenon are accelerated under high storage temperature and mainly lead to reduced hydration and swelling coefficients which in turn reduce cookability of seeds (Nasar-Abbas *et al*., 2008).

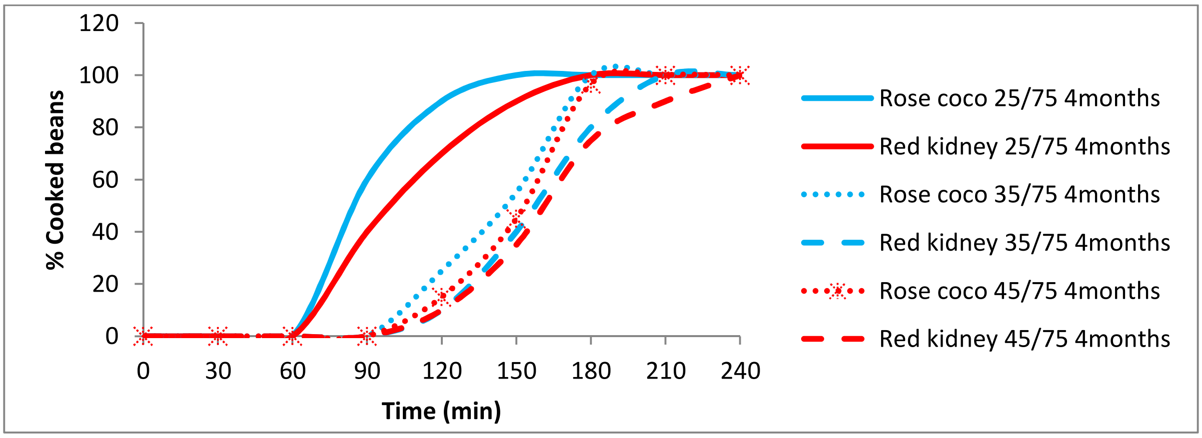

Figure 4: Cooking profile for Rose coco and Red kidney beans at 25^{0}C, 35^{0}C and 45^{0}C and constant relative humidity of 75% stored for 4 months

3.5 Effect of soaking pretreatments on cooking properties

Soaking in water is a common practice to soften texture and hasten the cooking process. The effect of the commonly used processing technique of soaking followed by cooking was able to determine the time it would take for the beans to cook. Cooking time is the most vital commercial quality characteristic of beans as consumers prefer bean varieties with shorter cooking times (Martinez- Manrique *et al.,* 2011). Prior grain soaking is directly related to cooking time which tends to decrease as beans remain immersed (Rodrigues *et al.,* 2005a and 2005b). The Na_2CO_3 and $CaCl_2$ cooking profile curves prior to cooking for 45 °C/75% RH are shown in Figure 5. Beans soaked in 0.1M $CaCl_2$ did not cook after five hours. The most significant improvement in cooking time was that obtained when the beans had been soaked in Na_2CO_3 as compared to de ionized water. Sodium carbonate had the most effect and distilled water the least effect on softening the texture of the beans. Hence, sodium carbonate had a significant effect on improving the hard texture of HTC beans while distilled water had the least effect on it. This confirms the beneficial effect of monovalent cations in decreasing the cooking time of both fresh and hardened beans. According to De Leon *et al* (1992), several mechanisms could be involved during the soaking and cooking process of the beans in the salt solution. Among this is ionic interaction whereby Na^+ tends to migrate into the bean and the Mg^{2+} and K^+ tend to leave the bean. With regard to improved cooking time, Coyoy Gonzalez (1987) states that the saline solutions improve heat transfer properties from the beans to its surroundings (diffusivity and thermal conductivity). De Leon (1987) gives evidence that sodium carbonate increase water absorption capacity and hence reduced cooking time. Additionally, the saline solutions increase the water holding capacity of the beans (Garcia- Vela, 1989).

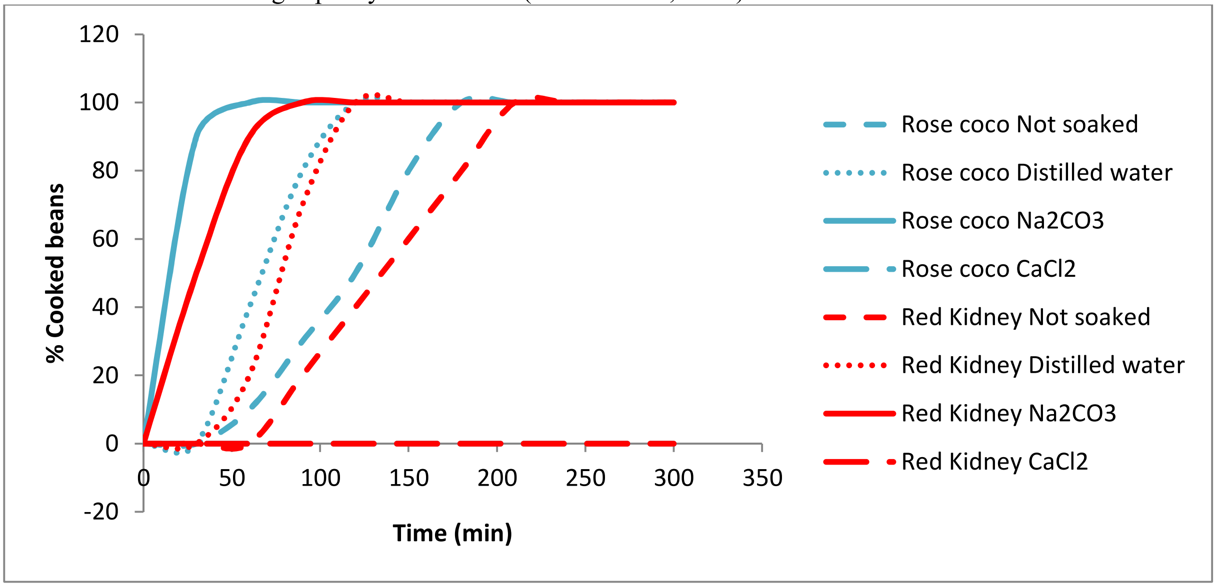

Figure 5: Comparison of soaking solutions at 45ºC/75%RH

3.6 Effect of storage conditions on moisture uptake during cooking

The moisture uptake curves for both Rose coco and Red kidney beans stored at 45 °C/75% RH and that of 35°C/83% RH are shown in Figure 6 and Figure 7 respectively. Both bean varieties at 0 month showed faster moisture uptake as compared to subsequent moisture uptake after the 2, 4 and 6 months storage times. For Rose coco bean stored at 45°C/75% RH, the moisture uptake reduced from 118% at 0 month to 89% at 6 months while Red kidney bean in the same conditions had a reduction from 114% at 0 month to 75% at 6 months. For Rose coco bean stored at 35°C/83% RH, the moisture uptake reduced from 118% at 0 month to 99% at 6 months while Red kidney bean in the same conditions had a reduction from 114% at 0 month to 91% at 6 months. In both storage conditions, Rose coco beans had higher moisture uptake rates as compared to the Red kidney bean. At 0 month, the uptake differs only slightly but the differences become significant with increase in storage time. Burr *et al.* (1968), Jackson and Varriano-Marston (1981) also reported faster initial water absorption rate for fresh beans when compared to the initial water absorption rate for HTC beans. Generally, the faster initial water/moisture uptake and shorter cooking time exhibited by the beans at 0 month compared to the beans in the subsequent months may be due to micro structural differences of the stored bean (Berrios *et.al.,* 1999).

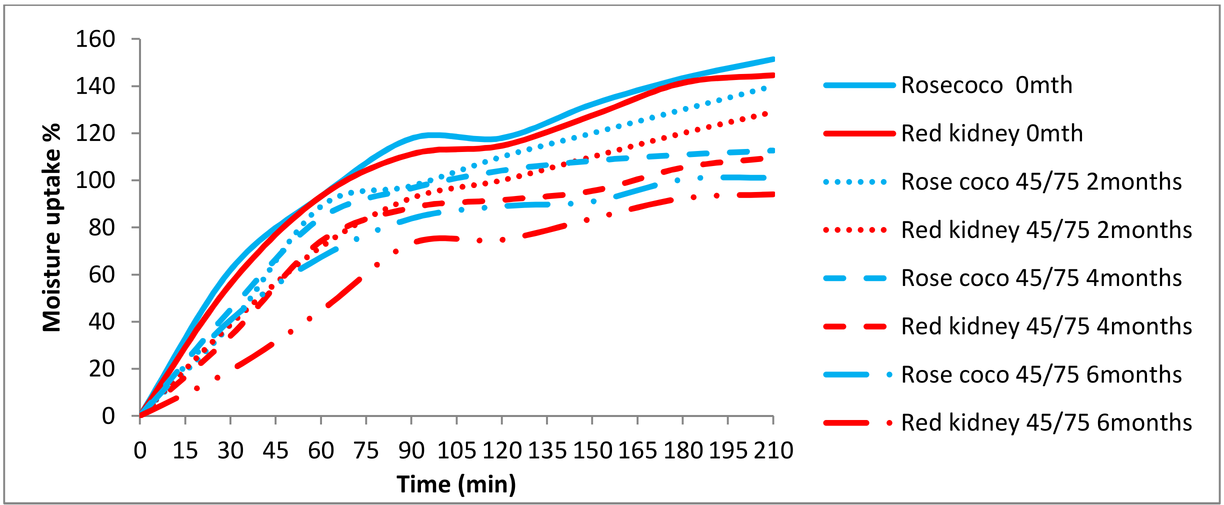

Figure 6: Moisture uptake curve for Rose coco and Red kidney beans at 45^{0}C / 75% RH during 0, 2, 4 and 6 months storage

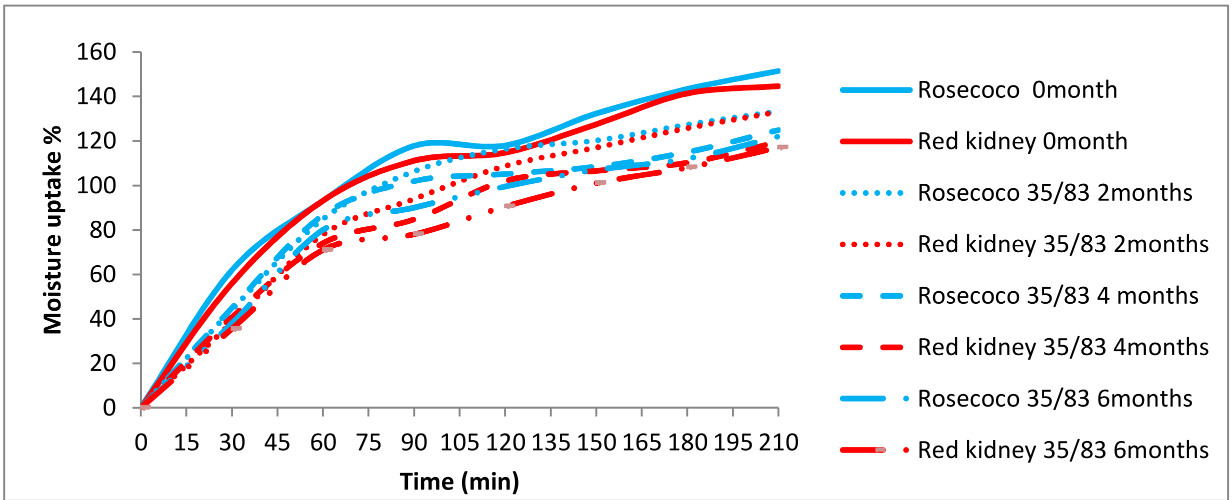

Figure 7: Moisture uptake curve for Rose coco and Red kidney beans at 35^{0}C / 83% RH during 0, 2, 4 and 6 months storage

4. Conclusion

Development of HTC defect in beans was a function of storage temperature, relative humidity and time. The results from physical characteristics, cooking profiles and moisture uptake during cooking points to development of HTC defect in Rose coco and Red kidney during conditions of high temperature (35˚C and 45˚C) and high relative humidity (75% and 83% RH). Soaking in sodium carbonate and distilled water were effective in reducing the cooking time with sodium carbonate shortening the cooking time significantly; however, calcium chloride increased the cooking time significantly. The development of HTC defect was more pronounced in Red kidney compared to Rose coco.

Acknowledgement
I wish to thank the technical staff in the Department of Food Science and Technology, Faculty of Agriculture of the Jomo Kenyatta University of Agriculture and Technology (JKUAT).

References

Batista, A., K., Prudencio, H., S., & Fernandes, F., K. (2010). “Changes in the functional properties and antinutritional factors of extruded hard to cook co mmo n beans *(Phaseolus vulgaris, L.)”Jo urnal of Food Science*, Vo l 5, Nr. 3.

Berrios, J.D.J., Swanson, G.B., Cheong A.W. (1999). “Physicochemical characterization of stored black beans *(Phaseolus vulgaris L.)” Food Research International* 32: 669-676

Broughton, W.J., Hernandez, G., Blair, M., Beebe, S., Gepts, P., Vanderleyden, J. (2003). "Beans *(Phaseolus spp.)*- Model food legumes". *P lant and soil* 252: 55-128. FAO. Netherlands.
Burr, H.K., Kon, S., & Morris,H. J. (1968). "Cooking rates of dry beans as influenced by moisture content and temperature and time of storage". *Food Technology*, 22,336-338.
Clemente, A., R. Sanchez-Vioque, J. Vioque, J. Bautista, and F. Milla. (1998). "Effect of processing on water absorption and softening kinetics in chickpea (Cicerarietinum L) seeds". *J. Sci. Food Agric*. 78:169–174.
Coyoy-Gonzalez, E.A. (1987). "Efecto de los Iones Na (Sodio) y K (Potasio) sobre el Tiempo de Coccion y las Caracteristicas de Transferencia de Calor en Enlatados de Frijol (*Phaseolus vulgaris*) Endurecido, ElaborADOS A Nivel Industrial. Tesis Ingeniero Quimico, Universidad de San Carlos de Guatemala, Guatemala, p.105.
De Leon, L. F., Elias, L. G., and Bressani, R., 1992. "Effect of salt solution on the cooking time, nutritional and sensory characteristics of common bean (*Phaseolus Vulgaris)". Food Res. Int. 25:131-137.*
De Leon, L. F. (1987). Soluciones Salinas: Una Tecnologia Economica para la Utilizacion del Frijol Comun (*Phaseolus vulgaris*) Endurecido. Tesis MSc. Universidad de San Carlos de Guatemala, Facultad de Ciencias Quimicas Farmacia: INCAP/CESNA/Curso de Postgrado en Cieciay Technologia de Alimentos, Guatemala, p.93.
Galiotou-Panayotou, M., Kyriakidis,B. N.& Margaris, I. (2008). "Phytase-phytate-pectin hypothesis and quality of legumes cooked in calcium solutions". *Journal of the Science of Food and Agriculture,* 88:355-361
Garcia – Vela, L.A. & Stanley, D.W. (1989). "Water holding capacity in hard-to cook beans (*Phaseolus vulgaris*): effect of pH and ionic strength". *J. Food Sci*, 54, 108-1
Hellevang, K., & Henson, R.A. (2000). "Management practices to Maintain Dry bean Grain quality. North Dakota State University."
Henteges, D.L., Weaver, C.M., & N ielsen, S.S.(1991). "Changes of selected physical and chemical components in the development of the hard to cook bean defect". *Journal of Food Science*, 56,436:442
Jackson,G.M.,& Varriano-Marston,E.(1981). "Hard to cook phenomenon in beans: effect of accelerated storage on water absorption and cooking time". *Journal of Food Science*, 46,799-803.
Jones, P.M.B. & Boulter, D. (1983). "The cause of reduced cooking rate in *Phaseolus vulgaris* following adverse storage conditions." *J Food Sci* 48:623-626
Kaur M. and S ingh N. (2007). "A comparison between the properties of seed, starch, flour and protein separated from chemically hardened and normal kidney beans." *J Sci Food Agric* 87: 729-737
Kilmer, L.O., Seib, A.P. & Heseney, C.R. (1994). "Effects of minerals and apparent phytase activity in the development of the Hard-to-cook state of beans." *Cereal Chem.* 71(5): 476-482.
Kinyanjui P. K., Njoroge D. M., Makokha A. O., Sila D. N (2015). "Hydration properties and texture fingerprints of easy- and Hard-to-cook bean varieties."
Liu, K. McWatters, K.H., & Phillips, R.D. (1992). "Protein insolubilization and thermal destabilization during storage as related to hard-to-cook defect in cowpeas." *Journal of agricultural and Food Chemistry*,40, 2483-2487
Martinez-Manrique E., Jacinto-Hernandez C., Garza-Garcia R., Campos R., Moreno E., & Bernal- L. (2011). "Enzymatic changes in pectic polysaccharides related to the beneficial effect of soaking on bean cooking time." Wileyonline library.com DOI 10.1002/JSFA.4474
Mattson,S. (1946). "The cookability of yellow peas: a colloid chemical and biochemical study." Acta Agric Suecana 2:185-231.
Mohsenin, N. N. 1980. "Physical properties of plant and animal material*." Gordon and Breach Science Publishers: New York, NY.*
Morris, H J., (1963). "Cooking qualities of dry beans*."* In 6th Annual Dry Bean Conference, Los Angeles. Pp11. USDA-ARS
Muneta, P.I., (1964). "The cooking time of dry beans after extended storage." *Food technology,* 18, 1240-1241.
Nasar-Abbas, S. M, Plummer, J. A, Siddique, K. H. M, White. P, Harris. D, Dods, K. (2008) "Cooking quality of Faba bean after storage at high temperature and the role of lignin and other phenolics in bean hardening." LWT *Food Sci Technol*. 41:1260-1267. Doi:10.1016/j.lwt.2007.07.017.
Ndungu, K., Emmambux, N. & Minaar, A. (2012). "Heat Pre-treatments to help alleviate the development of hard-to- cook cowpeas during storage." Department of food science, University of Pretoria, South Africa
Ockenden, I., Falk, D.E., & Lott, J.N.A. (1997). "Stability of phytate in Barley and bean during storage." *J Agric Food Chem* 45:1673-1677.
Reyes M.C., and Paredes L.O. (1993). "Hard to Cook phenomenon in common beans*."* Crit Rev *Food Sci N utr*. 33(3):227-86
Rodrigues, J.A., Ribeiro, N.D., Filho, A.C., Londero, P.M.G. (2005a). "Correlacao entre absorcao de agua e

tempo de cozimento de cultivares de feijao." Cienc. Rural. 35(1): 209-213, jan-fev

Rodrigues J.A., Ribeiro ND., Filho AC., Trentin M., Londero P.M.G (2005b). "Qualidade para o cozimento para o cozimento de graos de feijao obtidos em diferentes epocas de semeadura. Brag. 64(3): 369-376

Uebersax, M., & Bedford,C. (1980). "Navy bean processing: effect of storage and soaking methods on quality of canned beans." Research report 410, Michigan State University Agricultural Experiment Station. Pp11

Wang J and Kinsella JE (1976) "Functional properties of novel proteins; alfalfa leaf proteins." *J. Food Sci* . 41: 18-23.

Yousif, A.M.& Deeth, H.C.(2003). "Effect of storage time and conditions on the cotyledon cell wall of the adzuki bean (Vigna angularis)". *Food chem.* 81:169-174

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar