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THE EFFECTS OF PHYSICAL PROPERTIES OF COMMONLY GROWN BEAN (Phaseolus Vulgaris L) GENOTYPES ON COOKING TIME IN MACHAKOS COUNTY, KENYA

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ABSTRACT

Common bean (Phaseolus Vulgaris L.) is a food-secure and nutritious crop globally. It plays a big dietary role; supplying proteins, carbohydrates, essential elements and vitamins to both rural and urban households. However, its cook ability is constrained by hardness which influences cooking time and cost among the rural poor households. An experiment was carried out in Seed laboratory of Kenya Agricultural and Livestock Research Institute (KALRO)-Katumani, Machakos, Kenya to investigate the effects of physical properties on cooking time of different common bean varieties (KATX69, GLPX92, WAIRIMU, EMBEAN118, KATX56, EMBEAN14, KATB9, GLP2, KATB1, KATRAM, and KATSW-13) in a complete randomized design with three replications. Data was collected on differences of physical properties of bean varieties, effects of physical properties of bean on cooking time, and differences in hardness of different bean varieties. The data collected was subjected to analysis of variance (ANOVA) using SAS (version 9.3.3) to detect differences between treatments. The results of short rains (season one), showed that Embean118 recorded significantly ($p<0.05$) the highest length while Katsw-13 the lowest. The width didn't have significant difference among the varieties. The thickness of Embean118 was highest while Katsw-13 had the lowest. In long rains (season two), GLP2 and katram had the highest and lowest length respectively. The width of Katx56 was highest and Embean14 the lowest. Katsw-13 had the highest thickness while Katram had the lowest. In terms of hardness, KATX69 had the hardest testa in season one, while KAT SW-13 had the softest seed coat in the same season. In season two, KATRAM had the hardest seed coat while Embean 118 had the softest seed coat. Cooking time varied among the varieties where KATSW-13 and KAT B1 cooked significantly faster compared to other varieties in season one and two respectively. KATRAM took the significantly the longest time to cook in both seasons. The study recommends breeding of bean varieties with less permeable seed coat which will aid in their fast cooking as this would save cost on time and fuel.

Keywords: Physical properties, cooking time, Phaseolus Vulgaris L, hardness

1. INTRODUCTION

Globally, food legumes play an important role in the diets of most people, as they are regarded as' meat' for the poor (Kimatu *et al*., 2014). They are important food crops for simultaneously achieving three sustainable objectives in targeted population: - reducing poverty, improving human health and nutrition, and enhancing ecosystem resilience (Akibode and Maredia 2011). Among the pulses, common bean (*phaseolus vulgaris L*.) is the most widely produced and consumed crop in the world with low lipid and high content in proteins, vitamins, complex carbohydrates and minerals (Gathu and Njage 2012, Barros and Prudencio 2016). Beans have bioactive compounds such as flavonoids (anthocyanins and proanthocyanidins) and phenolic acids (mainly ferulic, caffeic, synaptic and Gallic acids) that are mostly found in seed coat (Ramirez Jimenez *et al.,* 2015 and Padhi *et al*., 2017). Some of them contribute to flatulence production in consumers while others reduce the availability of nutrients and cause growth inhibition (Moreno-Jiménez *et al*., 2015).

The Physical properties, such as seed size and weight, seed coat and cotyledon characteristics, influence pulse cooking quality (Pirhayati *et al.,* 2011). Cooking is the main method for eliminating the ant nutritional factors in beans to ensure acceptable consumption quality (Jogihalli *et al.,* 2017). Although, cooking quality may be affected by cultivar, seed characteristics, composition of seeds, growing location and environment (dos Santos Siqueira *et al.,* 2013) causes some physiological changes such as gelatinization of starch, denaturation of protein, solubilization of some polysaccharides, softening and breakdown of the middle lamella, a cementing material found in the cotyledon (Brennan *et al*., 2013). Prior to cooking, the beans are soaked in water for hours in order to soften them, reduce anti-nutritional substances, reduce cooking time and the cost of cooking fuel to improve the nutritional quality (Siah *et al.,* 2014). The breeders of common bean varieties aim at developing varieties with faster cooking time and market acceptability for both the packaging industry and consumer preferences (Santos *et al.*, 2016). The breeding of common bean for grain characteristics that cook faster is of great importance to bean consumers. Common bean hardness relationship between grain thickness and other characteristics may be concerned with grain commercialization (Silochi *et al* 2016). According to (Alam *et al.,* 2016) the beans that have a thinner outer skin are more easily hydrated during maceration, which in turn presents shorter cooking time, as the water favors the transfer of heat to the inside of the beans, facilitating the cooking. Information regarding the physical properties is very important in the design of equipment for harvesting, transporting, cleaning, separating, and packaging, storing and processing it into different foods (Siah *et al.*, 2014). Consumption of beans is limited due to the presence of several anti-nutritional factors, such as trypsin and chymotrysin inhibitors, phytates and lectins that impede the availability of nutrients (Hayat *et al.*, 2014). The objective of the current study was, therefore, to determine the effect of bean physical properties on cooking time in Machakos County, Kenya.

2.0 MATERIALS AND METHODS

2.1 Description of the site

The bean varieties used in this study were obtained from Kenya Agricultural and Livestock Research Organization, Katumani, Machakos County, Kenya, located at latitude 11^{0}35’S: longitude 37^{0}14’E, and 1560M above sea level.

2.2 Seed Management

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The bean varieties were grown and harvested from different crop seasons (short and long rains 2016). After harvesting the bean samples were naturally dried to a moisture content of 13% and placed in small paper bags of size 8 with a capacity of 3kg of the grains and dusted with pesticide and stored under normal room temperature and relative humidity. The beans had been stored for between 5 and 8 months under normal temperature and humidity conditions.

2.3 Seed preparation

After retrieval from the storage, the whole grains of each of the bean varieties were sorted by hand using a sieve of 2mm size to remove extremely small beans and broken ones, small stones, split seeds and defective seed coat or excessively dirty materials. These beans were cleaned and size-graded manually and categorized as follows: 20-30g-small, 31-40g-Medium, 41-50g-big. The bean varieties were selected based on the field records from the previous seasons which showed the characteristics of each variety and its yield stability over a range of conditions (biotic and a biotic stresses).The bean seeds were then rinsed with distilled water to eliminate insecticide residual before soaking and cooking. The grains were soaked in a container 8cm high, a diameter of 9.5 cm and a capacity of 1000ml with distilled water at varying soaking times of 3hr, 6hr, 12hr and 24hr.
The length (L), width (W) and thickness (T) were measured using a Vernier caliper reading to 0.01mm following perpendicular directions. An average of ten measurements was recorded from each variety. The bean hardness was performed using whole single grain and was subjected to crust hardness meter before and after soaking to measure the hardness of beans. Averages of six measurements were recorded from each variety. Cooking time was monitored using an automated Mattson Cooker (MBC) to get the mean cooking time (CT) of beans. The grains were positioned on the 25 reservoir like perorated saddles on the MBC that hold the grains. The vertical plunger on the MBC was placed on the surface of the grain, where it penetrated the grain after it sufficiently became soft and cooked. The cooking of the beans was proceeded by immersing MBC in a beaker with boiling water (98^{0}C) over a hotplate. Cooking time was recorded as the time in minutes needed to penetrate 50% of the beans; conventionally adopted as the falling time of the 13th plunger on the beans. All measurements were replicated three times.

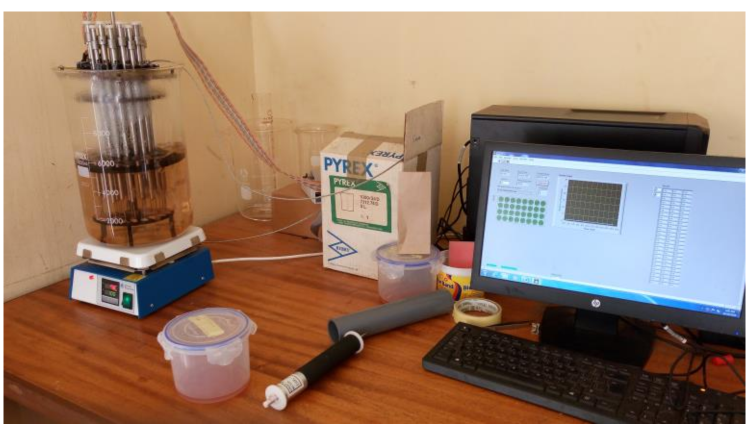

Figure 2: Shows the cooking process, when the cooking rack is immersed in boiling water, and the spread sheet for data recording as shown in Figure 2 above.

2.4 Statistical analysis

The collected data was analyzed using Analysis of Variance (ANOVA) using SAS: 9.1.3. Differences between the treatments at ($p \leq 0.05$) were considered significant and the treatment means were separated using Fisher's protected Least significant difference test (LSD) at $p \leq 0.05$ level.

3.0 RESULTS

3.1 The variation of length, width, thickness in mm of eleven bean varieties for Season one and season two

Differences of length, width and thickness were observed in seed samples of two seasons (Table 1). In season one, Embean118 had the longest length ($p \leq 0.05$) followed by GLP2, KATX56, KATX69, KATRAM, WAIRIMU, GLPX92; KATB9 was not different from KATB1; KATSW-13 recorded the lowest length. The width differed but was not significantly different from each other; KATB1 had the highest width followed by KATB9, KATRAM, GLP2; EMBEAN118 which was not different from EMBEAN14; GLPX92 which was not different from KATX69; followed by KATSW-13; and WAIRIMU recorded the lowest width.

The thickness of EMBEAN118 was highest; followed by GLP2, KATB9 and KAT B1 were not significantly different from each other, followed by GLP2, GLPX92, KATRAM, KATX69, EMBEAN14, KATX56, WAIRIMU AND KATSW-13 in that order. (Table 1)

In season two, GLP2 significantly ($p \leq 0.05$) had the highest length; GLPX92 was not significantly different from KATB1, WAIRIMU, KATX56, KATX69; EMBEAN118 was not different significantly different from EMBEAN14; KATB9, KATSW-13 and KATRAM had the lowest length. KATX56 had significantly ($p \leq 0.05$) the highest width followed by KATX69 and KATSW-13 which were not significantly different from each other followed by GLPX92, WAIRIMU, EMBEAN118, KATB9, GLP2, KATRAM, KATB1 in that order. EMBEAN14 had the lowest width. In terms of thickness, KATSW-13 and KAT X69 had significantly ($p \leq 0.05$) the highest thickness followed by EMBEAN118 followed KATB9, WAIRIMU,GLP 2, GLP X92 and KAT X56 which were not significantly different from each other followed by EMBEAN14, KATRAM, and KATB1; KATRAM had the lowest thickness in that order.

Table 1: The variation of length, width, thickness in mm of eleven bean varieties for Season one and season two

	season one			season two		
Variety	Length	width	Thickness	Length	width	Thickness
GLPX92	11.9c	5.3f	7.1d	15.2b	5.0b	6.2c
KATX69	14.8b	5.3f	6.7f	14.4e	5.4c	7.1a
Embean118	16.2a	5.5e	7.7a	12.3f	4.8d	6.9b
Wairimu	12.1c	4.1i	5.6i	15.c	4.9d	6.3c

Embean14	15.1b	5.5e	6.5g	12.3f	3.7h	5.6d
GLP2	15.5a	5.7d	7.2b	17.3a	4.4e	6.3c
KATX56	15.2b	5.1g	6.0h	14.7d	5.8a	6.3c
KatB9	11.3c	6.3b	7.3c	11.3g	4.5e	6.4c
Katram	13.7b	6.1c	7.0e	8.4i	4.3f	5.3e
KATB1	11.3c	6.7a	7.3c	15.2b	4.1g	5.6f
KATSW-13	8.0d	4.5h	5.3j	10.4h	5.4c	7.2a
LSD	0.20	0.13	0.90	0.23	0.10	0.12
C.V (%)	6.74	4.55	4.62	30.10	23.33	19.09

Means followed by the same letter within the columns are not significantly different (p<0.05) (Fisher's protected least significant difference (LSD).

3.2 Effects of bean grain hardness in Newton (N) by season and variety

Differences in hardness of beans were observed in two seasons (Table2). In season one, the bean varieties varied significantly (p≤0.05), at zero soaking time GLPX92 and KAT X69 were the hardest followed by, KATB1, KATRAM, Embean118 and Wairimu which were not significantly different from each other followed by KATB1, KATWS-13, GLP2 and Embean14 which were not significantly different from each other followed by and KATX56 in that order. Overall, KATX69, was the hardest followed by KAT B9, GLP X92, KATRAM which were not significantly different from each other, followed by Embean 118, Embean and Embean 14, followed by KAT B9,Wairimu and GLP 2 which were not significantly different from each other, followed by KAT X56 and KAT SW-13 in that order.

In season two, at zero hours KATB1 was the hardest followed by Katram, Embean14, Wairimu, KATB1, KATX69, Embean118,KATSW-13, KATX56, GLPx92 and GLP2 the lowest. Overall, KAT B1 was the hardest followed by KATRAM and Embean 14 which were significantly not ifferent from each other, followed by Wairimu, KAT B1, KAT B9, KAT SW-13,KAT X56,Embean 118 and GLP X92 which were not significantly different from each other.

Table 2: Hardness (N) of soaked and unsoaked bean varieties, degree of hydration during soaking and cooking time for two seasons

	Season one						Season two					
Variety	0hr	3hr	6hr	12hr	24hr	**Mean**	0hr	3hr	6hr	12hr	24hr	**Mean**
GLPX92	32.06 Aa	27.55 Aa	18.89 Be	13.45 Cd	8.28 Ce	**20.05b**	28.17 Af	22.17 Bb	15.83 Cc	9.17 Db	6.72 Da	**16.41c**
KATX69	31.39 Aa	26.34 Ab	20.00 Bc	17.28 Ca	9.56 Da	**20.91a**	29.94 Ae	20.56 Bd	8.55 Ch	6.84 Cd	5.17 Cc	**14.21d**

Embean 118	28.61 Ac	22.28 Af	19.33 Bd	13.50 Cd	8.39 Ce	**18.42c**	29.17 Af	18.39 Be	10.95 Cg	4.78 Dc	4.50 Dd	**13.56e**
Wairimu	28.56 Ac	24.89 Ad	14.67 Bf	13.61 Cd	8.06 Ce	**17.96d**	31.11 Ac	20.89 Bc	13.45 Cb	7.72 Dc	4.72 Dc	**15.58c**
Embean 14	25.55 Af	23.22 Be	18.56 Be	15.44 Cb	10.33 Ca	**18.62c**	31.95 Ab	27.89 Aa	19.94 Ba	9.44 Ca	4.83 Dc	**17.24b**
GLP2	25.78 Af	20.67 Bg	18.6 B1e	13.94 Cd	9.00 Cd	**17.6d**	20.56 Bg	21.77 Ac	15.50 Bc	9.77 Ca	5.17 Cc	**14.55d**
KATX56	23.06 Ag	17.28 Bh	13.66 Cg	12.56 Ce	9.89 Cb	**15.29e**	27.55 Af	21.50 Bc	12.89 Ce	5.95 Dd	4.61 Dc	**14.5d**
KATB9	27.89 Ad	25.50 Ad	20.33 Bb	16.61 Ba	9.00 Cd	**19.87b**	34.39 Aa	19.72 Bd	12.44 Cf	7.39 Dc	6.72 Da	**16.13c**
KATRAM	29.11 Ac	25.55 Bc	20.50 Ba	14.55 Cc	9.78 Cc	**19.90b**	32.22 Ab	22.72 Bb	17.44 Bb	8.33 Cb	6.39 Ca	**17.42a**
KATB1	30.67 Ab	25.17 Bd	15.06 Cf	11.61 Dg	7.44 Df	**17.99d**	30.06 Ad	18.61 Be	16.61 Bb	8.84 Cb	5.39 Cc	**15.90c**
KATSW-13	27.17 Ae	16.94 Bh	12.61 Bh	7.18 Ch	5.83 Cg	**14.55f**	28.72 Af	22.78 Bb	13.67 Cb	6.72 Dd	6.11 Db	**15.6c**
C.V%	**5.45**	**7.64**	**7.92**	**9.29**	**12,61**		**18.28**	**20.13**	**30.12**	**37.86**	**15.77**	
LSD along; across	**0.71 5.38**						**0.93 5.33**					

Means followed by the same letter within the columns are not significantly different p<0.05, (Fisher's protected least significant difference (LSD).

3.3 Effects of physical properties of bean varieties on cooking time

The physical varieties of beans affected cooking time significantly in both seasons (Table 3). In season one, KAT SW-13 took the shortest time to cook followed by KAT B1 and Embean 118, followed by KATx69,GLP92,Embean 14,GLP 2 and KAT X56 which were not significantly different from each other followed by KAT B9 and Wairimu which were not significantly different from each other followed by KATRAM which took the longest cooking time.

In season two, KAT B1 took the shortest time to cook followed by KAT SW-13,KAT X56 and Wairimu which were not significantly different from each other followed by KAT X69,Embean

118, Embean 14, GLP2, KAT B9 which were not significantly different from each other followed by KATRAM which took the longest time to cook.

TABLE 3: Effects of physical properties of bean varieties on cooking time

	Season one				Season two			
Variety	**Length**	**width**	**thickness**	**Cooking time**	**Length**	**width**	**thickness**	**Cooking time**
GLPX92	11.9c	5.3f	7.1d	111.87c	15.2b	5.0b	6.2c	108.34a
KATX69	14.8b	5.3f	6.7f	109.09c	14.4e	5.4c	7.1a	99.53b
Embean118	16.2a	5.5e	7.7a	105.81d	12.3f	4.8d	6.9b	97.43b
Wairimu	12.1c	4.1i	5.6i	115.04b	15.c	4.9d	6.3c	85.63c
Embean14	15.1b	5.5e	6.5g	108.59c	12.3f	3.7h	5.6d	96.71b
GLP2	15.5a	5.7d	7.2b	107.28c	17.3a	4.4e	6.3c	96.22b
KATX56	15.2b	5.1g	6.0h	107.13c	14.7d	5.8a	6.3c	85.35c
KatB9	11.3c	6.3b	7.3c	121.17b	11.3g	4.5e	6.4c	97.76b
Katram	13.7b	6.1c	7.0e	145.00a	8.4i	4.3f	5.3e	107.27a
KATB1	11.3c	6.7a	7.3c	97.80e	15.2b	4.1g	5.6f	78.74d
KATSW-13	8.0d	4.5h	5.3j	88.76f	10.4h	5.4c	7.2a	87.36c
LSD	0.20	0.13	0.90	6.97	0.23	0.10	0.12	5.98
C.V (%)	**6.74**	**4.55**	**4.62**	**13.49**	**30.10**	**23.33**	**19.09**	**9.39**

Means followed by the same letter within the columns are not significantly different (p<0.05) (Fisher's protected least significant difference (LSD).

4. DISCUSSION

4.1 The variation of length, width, thickness in mm of eleven bean varieties for Season one and season two

The variability observed in the physical characteristics (length, width and thickness) in the current study could be associated to genotypic characteristics of each variety in respect to environmental conditions. This is supported by an earlier study conducted by Hu *et al.*, (2013) indicating differences in seed sizes are due to genetic differences. Similarly studies conducted by Oomah *et al.*, (2010) and Gathu *et al.*, (2012) also attributed the differences in beans physical properties to differences in beans genotypes.

4.2 Bean grain varietal hardness (N) by season

The observed differences in hardness (N) of beans varieties in soaked and unsoaked state can be attributed to differences in the nature of the seed coat. This study concurs with an earlier study by Borji *et al.*, 2007 who attributed the differences in hardness of beans varieties to differences in hardness of the bean seed coat. Similar findings were reported by Wani *et al.*, 2017 who found differences in hardness of different seed varieties.

4.3 Effects of physical properties of bean varieties on cooking time

The observed differences in cooking time can be linked to the permeability of the bean seed coat which influences imbibition of water in the individual variety. Similar findings were reported by Borji *et al.*, (2007) who attributed differences in water imbibition by different varieties to differences in hardness of the seed coat. A Study by Mwami *et al*., 2017 attributed poor imbibition of bean grains to hard seed coat which negatively affects cooking time as indicated in a similar study by Wani *et al*., 2017.

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