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Genetic variability and inter-relationship between cooking time and some physico-chemical characteristics in pigeon pea (*Cajanus cajan* (l.) Millsp.) genotypes

Innocent Ezeorah Ezeaku * and Hakeem Ajeigbe

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Kano Station, PMB. 3491, Kano State, Nigeria.

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Abstract

Twenty two pigeon pea (*Cajanus cajan*) genotypes were evaluated for their physicochemical and cooking quality traits. There were significant differences among genotypes for seed weight (8.83-12.47 g), water absorption capacity (13.00-28.67 ml), seed hardness (17.00-21.70 Nm2), swelling ration (2.067-2.973 ml) and cooking time (66.67-86.67 min). Cooking time showed significant correlation with water absorption capacity and swelling ration indicating that these traits may be involved in controlling cooking time. The results of this study indicates that it is possible to develop cultivars with faster cooking time among pigeon pea cultivars through improvement in their water absorption capacity and swelling ration. Cultivar, ICPL 87091 which took lowest time to cook should be further investigated to determine additional qualities that could have influenced its cooking time.

Keywords: Pigeon Pea; Correlation Coefficient; Cooking Time; Variability; Physicochemical Traits

1. Introduction

Pigeonpea (*Cajanus cajan*) is a minor and underutilized grain legume which grows abundantly in many countries such as India, some regions of Africa, Central America, Australia and Asia [1]. Legumes rank second in importance to cereals as human food sources because they contain protein almost comparable to what is derived from animal and fish meat. Legumes, regarded as poor man's meat, are the cheapest sources of protein among the underprivileged that cannot afford animal and fish proteins [2]. The seeds and pods are consumed in many households as vegetable and also used as flour additives in soups and rice. It is an excellent food and protein source in developing tropical countries [3].

Pigeon pea seed contains moisture (10.1%), protein (18.8%), fat (1.9%), carbohydrates (53.0%), fiber (6.6%), and ash (3.8%). Additionally, the mineral and trace elements present in the legume are calcium (120 mg/g), magnesium (122 mg/g), copper (1.3 mg/g), iron (mg/g), and zinc (2.3 mg/g); vitamins are carotene (469.0 mg/g), thiamin (0.3 mg/g), riboflavin (0.3 mg/g), niacin (3.0 mg/g), and ascorbic acid (25.0 mg/g) [4]. The seed of the pigeon pea is enclosed in a hard, tough, and relatively thick skin that has a semi-permeable membrane. Movement of water through the mesocarp is restricted because the adhesive force that binds the mesocarp to the seed is relatively high [5]. Therefore, cooking is necessary to soften the firmly attached seed skin for convenient dehulling or eating. Whole legume takes much longer time for cooking than splits or washed dhal. Cooking time of un-soaked whole pigeon pea pulse ranged between 51 and 63 min while it took dhal (split pulse) between 19 and 31 min to cook [6]. Women cook whole pigeon pea using firewood overnight for about 8 - 12 h, which involves cost in terms of fuel, energy and also affects the nutritional quality adversely. For the urban low income families, the pulse is desirous for its taste but they cannot afford the required time nor fuel needed in its cooking [7].

Consumption of pulses is limited due to the presence of several anti-nutritional factors, such as a-galactosides, trypsin and chymotrypsin inhibitors, phytates and lectins that impede the availability of nutrients [8,9,10]. Heat treatment of

*Corresponding author: Innocent Ezeorah Ezeaku
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Kano Station, PMB. 3491, Kano State, Nigeria.

pulses involving cooking and roasting are used to remove antinutritional factors [11]. Cooking is the common processing method required to remove antinutritional factors and to ensure acceptable sensory quality of pulses [12,9]. Prior to cooking, pulses are usually soaked in water from few hours to overnight in order to save time and energy to cook [13]. Cooking also causes some physicochemical changes in pulses, including gelatinization of starch, denaturation of proteins, solubilization of some of the polysaccharides, and softening and breakdown of the middle lamella, a cementing material found in the cotyledon [14,15].

Physical properties, such as seed size, seed weight, seed coat and cotyledon characteristics, growing location and environment influence pulse cooking quality [16,17]. Cooking time is a heritable characteristic that differ widely amongst genotypes. It is widely affected by starch, permeability of seed coat, compactness of seed coat, endosperm and internal structure of the seed [18]. The consumer acceptability of pigeon pea will be significantly influenced by the cookability of the cultivars. In this light, the genetic variability of the cooking quality of cultivars of pigeon pea needs to be studied. Genetic variability can be used to breed good lines of pigeon pea in their phenotypic seed characteristic such as, color, texture, shape, size, compactness, etc. This method can also be employed in bringing about a change in the genetic constituents of pigeon peas that can influence cooking quality. With the increasing cost of fuel, it has become imperative to develop varieties that have better moisture absorption capacity and that can cook faster. Previous studies on the cookability of pigeon pea shows that, a reduction in the magnesium and calcium content of the cultivars will enable it to cook better and faster. This study was carried out to determine genetic variability present in whole seed of twenty two genotypes of pigeon pea and to correlate various physico-chemical parameters with the cooking time.

2. Material and methods

Twenty two genotypes of pigeon pea lines collected from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) breeding program were used for the experiment. The genotypes varied widely in their seed coat color (ranges from cream, black, orange, yellow, etc), seed size, seed weight and seed shape. The samples were cleaned properly before being utilized for the study. One hundred seeds were manually counted and then weighed on a digital weighing balance to obtain seed weight.

The experiment was conducted at the laboratory of the International Institute of Tropical Agriculture (IITA), Kano Station. The experiment was laid out in completely randomized design (CRD) in three replicates. Materials used for the study include beakers, 100m2 pot (containing racks), measuring cylinders, petri dishes, spatula, stop watch, cooker, hardness tester, flat board, thermometer, foil paper, digital scale, ovum and desiccator.

2.1. Determination of rate of water absorption and swelling ration

20 g of each variety was weighed. 70 ml of water was measured and poured into a graduated measuring cylinder. The 70 ml was recorded as the initial volume (Vi). The 20g of seeds were poured each into a separate cylinder. The increase in the volume of water was recorded as the final volume, (Vf). Each cylinder was covered with foil paper and left for 24 hrs to soak, after which the fully soaked volume was recorded. The apparent volume Va was recorded by separating the soaked seeds from the remaining water. The water was then measured and taken as the apparent volume. The volume of water absorbed was calculated as (Vi-Va).

The swelling ratio was also recorded by using the equation below:

$$= \frac{\text{Wet seed volume (wsv)}}{\text{Dry seed volume (dsv)}}$$

Where wsv is: Va-fully soaked volume of seed

And dsv is: Vf-Vi.

This procedure was repeated for each of the replicate.

2.2. Determination of seed hardness

For each set of genotypes in each of the 3 replicate, 3 seeds of the same size were collected and crushed using the hardness tester. The point at which the seed gets cracked or crushed is recorded as the hardness of the seed measured in Nm2.

2.3. Determination of seed coat and radicle weight

An accurately weighed sample of 10 g was soaked in 50ml distilled water for 16 hours at room temperature. After the water was drained, the seed coat of the soaked seeds were manually removed while the radicles were collected after splitting the cotyledon. The seed coats and radicles collected were dried in an oven at 60 ^{0} C for 24 h, followed by cooling in a desiccator. It was then weighed using digital scale to determine their weight in grams.

2.4. Determination of cooking time

The cooking time is defined as the time taken for pigeon pea to cook without prior soaking. A 100m2 pot containing racks was obtained and water was poured into 1/4th of it (not to cover the racks). Twenty two beakers were also filled with 60ml of water and were put into the pot and covered. The water was then allowed to reach boiling point of 100 degrees. This took about 20-30mins.10grams of each genotype was transferred into the beakers upon boiling and covered for an initial cooking time of 25mins after which, the seeds were checked at an interval of 10mins, until completely cooked. Samples (4–5 seeds) were withdrawn using a spatula at 5 min intervals up to 30 min and thereafter after every 2 min and tested. The cookability of the seeds is tested by placing the seed on the flat board and pressed with the thumb. When cooked, the seeds mash when the slightest pressure is applied. The above procedure is repeated for each of the replicate and across all the 22 genotypes. The time from addition of seeds till achievement of the desirable softness was recorded as the cooking time (min).

2.5. Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) and means were separated by Duncan multiple range test using GENSTAT version 8.1 [19]. Pearson's correlation coefficients of various properties of seeds were carried out to establish relationship between traits.

3. Results and discussion

The analysis of variance for twenty two pigeon pea genotypes is given in Table 1. Significant ($P \geq 0.05$) differences were recorded among all the lines for all the traits studied except seed coat and radical weights. Table 2 showed that 100 seed weight ranged from 8.83-12.47g with a mean of 10.56g. Similar result was reported by [20] who obtained seed weight in pigeon pea in the range of 7.40-12.00g. Water absorption capacity varied significantly ($P \geq 0.05$) from 13.00-28.67ml with a mean of 22.55ml. Hardness and swelling ratio were in the range of 17.00-21.70Nm2 and 2.067-2.973ml respectively and varied significantly ($P \geq 0.05$) among the genotypes. Conversely, seed coat and radicle weight did not vary among the genotypes. Cooking time on the other hand varied significantly among the genotypes and ranged between 66.67-86.67min with mean of 76.36min. The value reported here is similar to that reported by [21] on kidney bean (68.67-86.67min). Cooking time between 42.4-97.8min has been reported for different beans [22,23]. In this study, the lowest cooking time (66.67min) was found on genotype, ICPL 87091. Similarly, this genotype also possesses higher water absorption capacity and swelling ration. Previous study by [6] showed that cultivars with high water absorption capacity and swelling ratio resulted in lowered cooking time which corroborated this result. Coefficient of variation (%) ranged from 4.5 for seed hardness to 34.4 for radicle weight indicating that influence of extraneous factors on the expression of these traits was minimal. Several earlier studies also observed little influence of the environment on the expression of seed physiochemical traits in chickpea [24,25,26,27,28].

Table 1 Analysis of variance (ANOVA) for some physical and physico-chemical characteristics of twenty two pigeon pea genotypes

Sources	Degree of freedom	Seed weight (g)	Water absorption capacity (ml)	Seed hardness (Nm^2)	Seed coat weight (g)	Radicle weight (g)	Swelling ration (ml)	Cooking time (min)
Genotype	21	3.014**	43.335*	3.7621*	0.001237 ^{ns}	0.0001224^{ns}	0.15608*	114.0**
Error	42	1.850	2.833	0.7734	0.001049	0.0001776	0.04396	44.08

* = Significant at 5% probability level, ** = Significant at 1% probability level, ns = non-significant

Table 2 Physical and physico-chemical properties of twenty two pigeon pea genotypes

Genotype	Seed wt g/100	Water absorbed (ml)	Hardness (Nm^2)	Seed coat wt	Radicle wt	Swelling ratio (ml)	Cooking time (min)
ICP 7118	10.93	18.17	21.57	0.2767	0.0467	2.217	80.00
ICP 7120	9.90	14.67	20.90	0.3000	0.0467	2.163	70.00
ICP 8094	10.03	21.00	17.00	0.2800	0.0400	2.460	83.33
ICP 8863	11.07	25.33	20.27	0.2700	0.0300	2.750	73.33
ICP 9145	12.47	24.17	19.73	0.2633	0.0433	2.737	80.00
ICPL 151	10.40	28.67	20.17	0.2933	0.0467	2.973	73.33
ICPL 161	9.47	24.00	18.10	0.2733	0.0400	2.630	70.00
ICPL 7035	12.17	23.33	19.10	0.3333	0.0300	2.560	70.00
ICPL 84023	10.70	24.33	21.70	0.2667	0.0333	2.597	76.67
ICPL 84031	10.37	24.33	20.07	0.3133	0.0433	2.607	76.67
ICPL 85010	10.37	22.67	20.10	0.2800	0.0433	2.503	70.00
ICPL 85012	11.30	26.67	19.70	0.3267	0.0433	2.813	73.33
ICPL 85063	11.47	23.17	20.80	0.2667	0.0333	2.580	80.00
ICPL 86012	10.23	16.67	19.57	0.2967	0.0467	2.077	86.67
ICPL 87	9.30	24.33	18.03	0.2633	0.0233	2.510	86.67
ICPL 87051	11.53	23.33	18.97	0.2967	0.0400	2.577	86.67
ICPL 87091	11.87	26.00	19.40	0.3133	0.0333	2.660	66.67
ICPL 87119	11.17	24.00	19.10	0.2900	0.0400	2.620	70.00
ICPL 88039	9.67	23.33	19.47	0.2800	0.0333	2.617	76.67
MN 1	8.83	13.00	20.77	0.2900	0.0400	2.067	83.33
MN 5	10.17	23.17	19.93	0.2800	0.0367	2.613	73.33
UPAS 120	9.00	21.67	20.13	0.2667	0.0400	2.490	73.33
Mean	10.56	22.55	19.75	0.2873	0.0388	2.537	76.36
LSD (0.05)	2.241	2.773	1.449	0.05336	0.02196	0.3455	10.940
CV (%)	12,9	7.5	4.5	11.3	34.4	8.3	8.7

The correlation coefficients among all the seven physico-chemical and cooking properties of pigeon pea genotypes are summarized in Table 4. Correlation coefficients between water absorption capacity and seed weight (0.2780), swelling ratio and seed weight (0.2123), cooking time and water absorption (-0.1963), cooking time and swelling ration (-0.2398), swelling ration and water absorption (0.8679) and radicle weight and seed coat weight (0.6437) were found to be significant at 5% level of probability. The observed negative correlation between water absorption and swelling ratio with cooking time reveals that with the increase in these two traits cooking time decreases. [29] had also stated that the amount of water absorbed and solids dispersed during cooking were highly correlated with cooking time of pigeon pea *dhal.* [30] found out that small seeds tend to cook faster than larger seeds. In the present study there was no significant correlation between seed weight and cooking time. This observation was in agreement with that of [31,32] who found no significant correlation between seed size and cooking time in sixty genotypes of mung bean and in dhal field peas respectively.

Table 3 Comparison of means of physical and physico-chemical characteristics of twenty two pigeon pea genotypes

Seed weight g/100	Water absorbed (ml)	Hardness (Nm²)	Seed coat weight	Radicle weight(g)	Swelling ratio (ml)	Cooking time (min)
MN 1 8.83 a	MN 1 13.00a	ICP 8094 17.00a	ICP 9145 0.26a	ICPL 87 0.02a	MN 1 2.07a	ICPL87091 6.67 a
UPAS 120 9.00a	ICP 7120 14.67ab	ICPL 87 18.03ab	ICPL 87 0.26a	ICP 8863 0.03a	ICPL 86012 2.08a	ICP 7120 70.00 a
ICPL 87 9.30a	ICPL 86012 16.67bc	ICPL 161 18.10ab	ICPL 84023 0.27a	ICPL 7035 0.03a	ICP 7120 2.16ab	ICPL 161 70.00 a
ICPL 161 9.47a	ICP 7118 18.17c	ICPL 87051 18.97bc	ICPL 85063 0.27a	ICPL 84023 0.03a	ICP 7118 2.21abc	ICPL 7035 70.00 a
ICPL 88039 9.67a	ICP 8094 21.00d	ICPL 7035 19.10bcd	UPAS 120 0.27a	ICPL 85063 0.03a	ICP 8094 2.46abcd	ICPL85010 70.00 a
ICP 7120 9.90a	UPAS 120 21.67de	ICPL 8711 19.10 abcd	ICP 8863 0.27a	ICPL 87091 0.03a	UPAS 120 2.50abcd	CPL 87119 70.00 a
ICP 8094 10.03a	ICPL 85010 22.67de	ICPL 87091 19.40bcd	ICPL 161 0.27a	ICPL 88039 0.03a	ICPL 85010 2.50abcd	ICP 8863 73.33 a
MN 5 10.17a	ICPL 85063 23.17de	ICPL 88039 19.47bcd	ICP 7118 0.28a	MN 5 0.04a	ICPL 87 2.51abcd	ICPL 151 73.33 a
ICPL 86012 10.23a	MN 5 23.17de	ICPL 86012 19.57bcd	ICP 8094 0.28a	ICPL 87119 0.04a	ICPL 7035 2.60abcd	ICPL 85012 73.33 a
ICPL 84031 10.37a	ICPL 7035 23.33de	ICPL 85012 19.70bcd	ICPL 85010 0.28a	ICP 8094 0.04a	ICPL 87051 2.67abcd	MN 5 73.33 a
ICPL 85010 10.37a	ICPL 87051 23.33de	ICP 9145 19.73bcd	ICPL 88039 0.28a	ICPL 161 0.04a	ICPL 85063 2.58abcd	UPAS 120 73.33 a
ICPL 151 10.40a	ICPL 88039 23.33de	MN 5 19.93bcd	MN 5 0.28a	ICPL 87051 0.04a	ICPL 84023 2.60abcd	ICPL 84023 76.67 a
ICPL 84023 10.70a	ICPL 161 24.00de	ICPL 84031 20.07bcd	ICPL 87119 0.29a	MN 1 0.04a	ICPL 84031 2.61abcd	ICPL 84031 76.67 a
ICP 7118 10.93a	ICPL 87119 24.00de	ICPL 85010 20.10bcd	MN 1 0.29a	UPAS 120 0.04a	MN 5 2.61abcd	ICPL 88039 76.67 a
ICP 8863 11.07a	ICP 9145 24.17de	UPAS 120 20.13bcd	ICPL 151 0.29a	ICP 9145 0.04a	ICPL 88039 2.62abcd	ICP 7118 80.00 a
ICPL 87119 11.17a	ICPL 84023 24.33de	ICPL 151 20.17bcd	ICPL 86012 0.30a	ICPL 84031 0.04a	ICPL 87119 2.62abcd	ICP 9145 80.00 a
ICPL 85012 11.30a	ICPL 84031 24.33de	ICP 8863 20.27bcd	ICPL 87051 0.30a	ICPL 85010 0.04a	ICPL 161 2.63abcd	ICPL 85063 80.00 a
ICPL 85063 11.47a	ICPL 87 24.33de	MN 1 20.77cd	ICP 7120 0.30a	ICPL 85012 0.04a	ICPL 87091 2.66abcd	ICP 8094 83.33 a
ICPL 87051 11.53a	ICP 8863 25.33def	ICPL 85063 20.80cd	ICPL 84031 0.31a	ICP 7118 0.05a	ICP 9145 2.74bcd	MN 1 83.33 a
ICPL 87091 11.87a	ICPL 87091 26.00def	ICP 7120 20.90cd	ICPL 87091 0.31a	ICP 7120 0.05a	ICP 8863 2.75bcd	ICPL 86012 86.67 a
ICPL 7035 12.17a	ICPL 85012 26.67ef	ICP 7118 21.57cd	ICPL 85012 0.33a	ICPL 151 0.05a	ICPL 85012 2.81cd	ICPL 87 86.67 a
ICP 9145 12.47a	ICPL 151 28.67f	ICPL 84023 21.70d	ICPL 7035 0.33a	ICPL 86012 0.05 a	ICPL 151 3.07d	ICPL 87051 86.67 a

Mean values in the same column with different superscripts are significantly ($p > 0.05$) different

Table 4 Correlation coefficient of physical and physico-chemical characteristics of twenty two pigeon pea genotypes

Seed weight (g)	1	-						
Water absorbed (ml)	2	0.2780*	-					
Hardness (Nm^2)	3	0.1367	-0.1800	-				
Seed coat weight (g)	4	0.1765	0.1049	-0.1558	-			
Radicle weight (g)	5	0.0962	-0.1189	0.0270	0.6437**	-		
Swelling ratio (ml)	6	0.2123*	0.8679**	-0.1081	0.1060	-0.0253	-	
Cooking time (min)	7	-0.0096	-0.1963*	-0.0580	-0.0739	-0.0277	-0.2398*	-
		1	2	3	4	5	6	7

** And * = Correlation is significant at 0.01 and 0.05, respectively.

4. Conclusion

The present study reveals that there was genetic variation among pigeon pea lines for water absorption capacity, 100 seed weight, swelling ratio and cooking time of pigeon pea seeds. This finding therefore offers opportunity for breeding and selection of candidate pigeon pea lines. High negative significant correlation was observed between cooking time and swelling ratio, and between water absorption and swelling ratio. This is especially important for breeding for early cooking time which translates to energy saving in processing of pigeon pea for home consumption. Large number of pigeon pea lines should be further evaluated to obtain the full extent of variation and selections of parents for breeding programs.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest amongst themselves.

Authors' contribution

IEE conceived, designed the experiment and collected the data. HA analyzed the data and produced the tables. All authors interpreted the data, critically revised the manuscript for important intellectual contents and approved the final version.

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