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Characterization, association and path analysis studies of different cooking quality/ physicochemical parameters in green seeded chickpea genotypes

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Abstract
Ninty green chickpea (*Cicer arietinum* L.) genotypes were evaluated for different cooking quality parameters/physicochemical parameters, like, hydration capacity, swelling capacity, swelling index, seed density, seed volume, seed size or test weight and cooking time. This whole experiment is conducted during 2016-2017 at ARS Kalaburagi, (UAS, Raichur, Karnataka, India). The rage of minimum, maximum and mean value for each cooking quality parameter is calculated. The Analysis of variance (ANOVA) showed mean sum of squares (MSS) for green chickpea genotypes is highly significant for all the cooking quality parameters studied in the present investigation except swelling index and seed density for 100 seed weight. Among seven cooking quality parameters studied, cooking time, hydration capacity, seed volume and swelling capacity revealed significant and positive association, seed density showed non-significant but positive association, whereas seed index revealed negative non-significant association with seed size or test weight(100 g). All the cooking quality parameters revealed positive direct effect on seed size or test weight except seed index at phenotypic level.

Keywords: Path analysis studies, cooking quality, green seeded chickpea

Introduction
Chickpea (*Cicer arietinum* L.) is one of the most readily produced and consumed pulses (grain legumes) worldwide, particularly in the Indian subcontinent and Mediterranean countries (FAO 2004) [8]. It is considered to be a healthy vegetarian food and is one of the most important human and domestic animal foods in south Asia. In addition to proteins, it is a good source of carbohydrates, minerals and trace elements like, calcium, magnesium, zinc, potassium, iron, phosphorus and vitamins like, thiamine and niacine required to human body (Duke, 1981; Huisman and Van der-Poel, 1994; Williams and Singh, 1988) [6, 13, 38] and (Zia-Ul-Haq *et al.*, 2007) [41]. There are two types of chickpea: the small angular “desi”; and the large rounder “kabuli” (Saxena and Singh 1987) [29]. Most kabuli and about 30% of desi chickpeas are soaked (hydrated) before cooking and soaking is important for both domestic use as well as industrial processing, so the process of soaking and cooking can reduce gas production in humans (and monogastric animals) from anaerobic degradation/fermentation of oligosaccharides by intestinal bacteria (Jood and others 1985; Ruperez 1998) [16, 27] *via* partial leaching of the substrate. Soaking is often, but not always, a prelude to cooking pulse seeds. Pre-soaking can reduces the cooking time required to achieve the desired softness, and shorter cooking time is convenient which may demand less fuel, a scarce commodity in developing countries (Geervani and Theophilus 1980; Usha and others 1981; El Faki and others 1984; Salunkhe and Kadam 1989; Ward and others 1995; Abu-Ghannam 1998) [10, 11, 33, 7, 28, 36, 1]. In the canning industry, fully hydrated and swollen seeds are required to fill cans prior to retort cooking under pressure (Drake and Muehlbauer 1985; van Buren and others 1986) [5, 34]. Hydration and cooking are two separate but related processes: hydration needs to occur before or during cooking for seed to soften and starch to gelatinize, the two characteristics that define a cooked seed. Methods for quantifying maximum hydration/swelling using the “hydration/swelling capacity” method in chickpea and other pulses are well established (Williams and others 1988; Burridge and others 2001) [37, 2]; however, there is no commonly accepted method for estimating hydration and swelling rates. Cooking time is a highly significant aspect of cooking quality, factors such as nutritional value, flavour, odour and texture of the cooked product are also important for both acceptance and suitability of the chickpeas as a human food. Along with dietary value, chickpea eminence is also judged by

physiochemical and cooking traits (Patane, 2006) [26], which are very important attributes. The greater part of work on the cooking and nutritive quality of chickpeas has justifiably been confined to the desi type of chickpeas, since these comprise about 85% of world chickpea production. A search **of** the literature since 1930 did not reveal any information dealing with the cooking quality of kabuli-type chickpeas (Singh *et al*., 1977) [30].

When a partially cooked chickpea is pressed with the fingers it separates neatly into its two cotyledons. The uncooked portion in the centre of the cotyledons is white to whitish-yellow, while the cooked portion is yellow. The size of the white un-gelatinized area relative to the total area of the cotyledons is clearly distinguishable, and affords a method of assessing the degree of cooking of the chickpea which is less subjective than pressure methods. Cooking time is defined as the time from commencement of boiling until 90 to 100% of the seeds are cooked, as determined by visual determination of the degree of gelatinization, and also softness of the seeds as determined by pressure of the fingers. The study was developed as an attempt to increase laboratory throughput by employing methods for predicting cooking time in large numbers of genotypes.

Cooking time may be expected to be affected by the starch itself, the permeability of the seed coat, and by the internal structure of the seed endosperm material, all of which would be affected by soaking in water. Genetic analysis of seed quality traits is pre-requisite for breeders in selection of desired genotypes. The variation in seed physical parameters depends upon numerous factors such as genotype, seed characteristics, seed composition, climatic factors etc. A few reports are available on various quality traits and their utilization in breeding programs. Waldia *et al.* (1996) [35] evaluated kabuli chickpea genotypes for seed physical and gravimetric properties and their role in cooking quality; Yadav and Sharma (1999) [40] had found substantial variation for seed weight in more than 100 chickpea genotypes. Mehla *et al.* (2001) [21] studied 55 chickpea genotypes for physical characters. Seed mass, seed volume, swelling capacity and hydration capacity were important quality attributes that were mutually correlated. Singh *et al.* (2003) [32] estimated genetic diversity for consumer's quality traits in chickpea. Dry and soaked weight of 100 grains, seed volume, hydration capacity and swelling capacity contributed towards genetic diversity.

Though several reports are available on physical and chemical characteristics of chickpea, limited information is available on the green seeded chickpeas for different cooking quality traits. The information available on the role/influence of physicochemical properties and seed traits on cooking time is also sparse. Therefore, the present investigation was undertaken to assess the association and path analysis of chickpea genotypes for different physicochemical or cooking quality traits.

Materials and methods

A) Experimental design, materials and growing conditions

An experimental material consisting of 90 green seeded chickpea genotypes derived RGK lines (F5 lines of GKB-10 × MNK-1). The derived lines includes green chick pea seeds of advanced generation, like Raichur green kabuli (RGK) 33 genotypes, wilt resistance green kabuli (WRGK) 12 genotypes, high seed size green kabuli (HSSGK) 10 genotypes, small seed size green kabuli (SSSGK) or chinoli types 6 genotypes, single plant selection green kabuli (SPSGK) 29 genotypes along with this 4 checks like MNK-1 (milky white kabuli type seeds), GKB-10 (green desi type seeds) are the parents of advanced generations and KAK-2, JG-11 were used to achieve the objectives (Table 1). These genotypes were grown in augmented design with six blocks and each block having 19 genotypes including 4 checks, the block is of having 75m length and 4m width, 2 lines of each entry are space planted at 30 cm ×10 cm under normal planting on 7th October 2016. All the seed material of advanced generation of green seeded chick pea (RGK entries), and checks which are used to carry out this experiment were procured from ARS Kalaburagi, UAS Raichur. In field condition recommended cultural practices were carried out to maintain healthy crop growth and good crop stand. Further while recording data for different observation we have followed standard protocol given in chickpea descriptor (ICRISAT, IBPGR, ICARDA, 1985).

Table 1: List of green seeded chickpea genotypes used in the present experiment

S. No.	Genotypes	S. No.	Genotypes	S. No.	Genotypes
Raichur green kabuli (RGK)		**Wilt resistance green kabuli (WRGK)**		**Single plant selection RGK (SPSRGK)**	
1	RGK-1-15	31	WRGK-31-15	59	RGK-1-15-1
2	RGK-2-15	32	WRGK-32-15	60	RGK-2-15-2
3	RGK-3-15	33	WRGK-33-15	61	RGK-3-15-3
4	RGK-4-15	34	WRGK-34-15	62	RGK-5-15-5
5	RGK-5-15	35	WRGK-35-15	63	RGK-6-15-6
6	RGK-6-15	36	WRGK-36-15	64	RGK-7-15-7
7	RGK-7-15	37	WRGK-37-15	65	RGK-8-15-8
8	RGK-8-15	38	WRGK-38-15	66	RGK-9-15-9
9	RGK-9-15	39	WRGK-39-15	67	RGK-10-15-10
10	RGK-10-15	40	WRGK-40-15	68	RGK-11-15-11
11	RGK-11-15	41	WRGK-41-15	69	RGK-12-15-12
12	RGK-12-15	42	WRGK-42-15	70	RGK-13-15-13
13	RGK-13-15	**High seed size green kabuli (HSSGK)**		71	RGK-14-15-14
14	RGK-14-15	43	RGK-43-15	72	RGK-15-15-15
15	RGK-15-15	44	RGK-44-15	73	RGK-16-15-16
16	RGK-16-15	45	RGK-45-15	74	RGK-17-15-17
17	RGK-17-15	46	RGK-46-15	75	RGK-18-15-18
18	RGK-18-15	47	RGK-47-15	76	RGK-19-15-19
19	RGK-19-15	48	RGK-48-15	77	RGK-20-15-20
20	RGK-20-15	49	RGK-49-15	78	RGK-21-15-21
21	RGK-21-15	50	RGK-50-15	79	RGK-22-15-22
22	RGK-22-15	51	RGK-51-15	80	RGK-23-15-23
23	RGK-23-15	52	RGK-52-15	81	RGK-24-15-24
24	RGK-24-15	**Small seed size green kabuli (Chinoli type) (SSGK)**		82	RGK-25-15-25
25	RGK-25-15	53	CB-53-15	83	RGK-26-15-26
26	RGK-26-15	54	CB-54-15	84	RGK-27-15-27
27	RGK-27-15	55	CB-55-15	85	RGK-28-15-28
28	RGK-28-15	56	CB-56-15	86	RGK-29-15-29
29	RGK-29-15	57	CB-57-15	87	RGK-30-15-30
30	RGK-30-15	58	CB-58-15	88	RGK-E-1-15
				89	RGK-E-2-15
				90	RGK-E-3-15

S. No.	Checks			
1	MNK-1	3	JG-11	
2	GKB-10	4	KAK-2	

B) Physicochemical or cooking characteristics

Different cooking quality parameters like, hydration capacity, hydration index, swelling capacity, swelling index, cooking time (min.) and 100-seed weight were evaluated as described below:

100-seed weight (g) / test weight (g): Average weight of 100 seeds which is measured in terms of grams. Different classes of seed seed size are mentioned in (Table. 2) 100 seed weight is also used to measure seed size in chick pea.

Table 2: class of Seed size in chickpea

S. No.	Classes/Types/seed size	Seed weight (g)
	Desi	
1	Nano seed	< 10
2	Small seed	20-25
3	Large seed	> 25
	Kabuli	
1	Nano seed	< 20
2	Small	20-30
3	Large	>30
4	Extra large	>50

(Chickpea descriptor, IBPGR, ICARDA, ICRISAT, 1985)

1. **Initial weight (W_0):** Initial weight was recorded as weighing of 100 seeds without soaking by using weighing balance.
2. **Final weight (W_f):** Final weight was recorded as weighing of 100 seeds 24 hours after soaking of seeds by using balance.
3. **Initial volume (V_0):** The 20ml of water is transferred to 100ml measuring cylinder after that 100seeds are transferred to same measuring cylinder then we get the volume of 100 seeds and 20 initial water levels. Initial volume (**V_0**) is recorded by deducting the 20 with total volume.
4. **Final volume (V_f):** The 40ml of water is transferred to 100ml measuring cylinder after that 100seeds of 24 hours soaked are transferred to same measuring cylinder then we get the volume of 100 seeds and 40 initial water level. Final volume (**V_f**) is recorded by deducting the 40 with total volume.

Hydration capacity (HC, g water/ seed): 100 seeds were transferred to a 200ml Erlenmeyer flask and 100ml de-mineralized water was added. The flask was tightly closed and left overnight (16 h) at room temperature. The following day, the seeds were drained, superfluous water was removed with help of a paper towel and seeds were reweighed. It is expressed as percentage and calculated using the formula: $HC = (W_f - W_0)/100$. Where, W_f is the weight of 100 seeds after 16 h soaking; W_0 is the weight of 100 seeds before soaking.
Swelling capacity (SC, ml /seed): After reweighing, the soaked seeds were transferred to a 200ml measuring cylinder and 100ml water was added. It is expressed as percentage and calculated using the formula: $SC = (V_f - V_0)/100$. Where, V_f is the volume of 100 seeds after 16 h soaking; V_0 is the volume of 100 seeds before soaking.
Swelling index (SI): The ratio between swelling capacity and seed volume. Ie., Swelling capacity/Seed volume.
Seed density (g /ml): The ratio between seed weight and seed volume. Ie., Weight of 100 seeds/ Volume of 100 seeds
Cooking time (min.): 25 seeds of each sample were soaked in 100ml de-mineralized water for 12 h. After 12 h, the samples were cooked in 100ml water at 100˚C. The temperature was maintained constant throughout, until the samples were cooked. Seeds were cooked until soft when pressed between the fingers to check for softness.

C) Statistical analysis
The data was subjected to statistical analysis by statistical software WINDOSTAT package, 8.1version. Pearson correlation coefficient is a statistical measure which is used to find out the degree and direction of relationship between two or more variables. It is represented by r. Genotypic and phenotypic correlation coefficients were calculated according to the method followed by Singh and Chaudhary (1979); and Cochran and Cox (1992) [4].

Results
The Analysis of variance (ANOVA) showed mean sum of squares (MSS) for green seeded chickpea genotypes Vs checks are highly significant for all the cooking quality parameters studied (hydration capacity, swelling capacity, seed volume, seed size and cooking time) in the present investigation except swelling index and seed density (Table.3).
Analysis of cooking quality parameters like, hydration capacity, swelling capacity, swelling index, seed density for 100 seed weight, seed volume, seed size or test weight and cooking time exhibited greater variation for mean, minimum and maximum. Hydration capacity is ranged from 0.07 g/ seed to 0.78 g/ seed with an average of 0.26 g/ seed, swelling capacity is ranged from 0.09 ml/ seed to 0.75 ml/ seed with a mean of 0.263 ml/ seed, swelling index is ranged from 0.01 ml/ seed to 0.13 ml/ seed with a mean of 0.02 ml/ seed, seed density for 100 seed weight is ranged from 1.30 g/ml to 8.10 g/ml with a mean of 1.80 g/ml, seed volume is ranged from 3.00 ml/100 seeds to 47.00 ml/100 seeds with a mean of 17.55 ml/100 seeds, seed size or test weight is ranged from 15.00 g to 64.80 g with a mean of 27.12 g and cooking time is ranged from 55.00 min. to 72.00 min. with a mean of 59.66 min. (Table 4).

Inter- correlation among the cooking quality parameters
Pooled data on association and inter-correlation for different cooking quality parameters for 90 green seeded chickpea genotypes were presented in (Table.5). Among all the cooking quality parameters studied, seed size shows highest positive correlation with cooking time followed by hydration capacity, seed volume and swelling capacity except seed density and seed index where it revealed positive and negative association with seed size respectively. While the overall association of all the parameters contributed to each other through the influence of following independent traits. Further inter correlation among the important parameters, hydration capacity has Shows highest positive significant association with seed size (0.829), followed by cooking time (0.776), swelling capacity (0.466), however this parameter also reported non-significant but positive association with seed density and swelling index of (0.169, 0.011) respectively. The swelling capacity shows highest positive significant association with swelling index (0.506), followed by hydration capacity (0.466), seed size (0.387), seed density for 100 seed weight (0.339) and cooking time (0.331) while, this parameter also recorded non-significant but positive association with seed volume (0.136). The swelling index has Shows highest positive significant association with seed density for 100 seed weight (0.889) followed by swelling capacity (0.506) and positive non-significant association with hydration capacity (0.011), however this parameter also manifested as significant negative association for seed volume (0.589) followed by negative but non-significant association with cooking time and seed size or test weight as (0.121, 0.114) respectively.
The seed density for 100 seed weight exhibited highest

positive significant association with swelling index (0.889), followed by swelling capacity (0.339) and positive non-significant association for hydration capacity (0.169), cooking time (0.085) and seed size (0.078), while this parameter also displayed strong negative correlation for seed volume (0.610). The seed volume shows strong positive association for seed size (0.646), followed by cooking time (0.624) and hydration capacity (0.450) further, it also been accounted for positive non-significant association with swelling capacity (0.136), while this parameter exhibited strong negative significant association with seed density for 100 seed weight and swelling index of (0.610, 0.589) respectively. Cooking time has recorded highest strong positive significant association for seed size or test weight (0.976), followed by hydration capacity (0.776), seed volume (0.624) and swelling capacity (0.331) while, it shows lowest positive non-significant association with seed density for 100 seed weight (0.085), however cooking time has Showsa negligible negative association for swelling index (0.121). Seed size or test weight imposed strong positive significant inter-relation with cooking time (0.976), succeed by hydration capacity (0.829), seed volume (0.646) and swelling capacity (0.387), while seed density (0.078) for 100 seed weight reported negligible positive relation with seed size, however swelling index (0.114) show non-significant association with seed size.

Direct effects on seed size or test weight (Table. 6)

Six out of seven parameters has positive and direct effect on seed size or test weight at phenotypic level. The parameter cooking time (0.6685) has recorded highest direct effect on seed size or test weight succeeded by seed density (0.2677) for 100 seed weight, seed volume (0.2048) and hydration capacity (0.1371). Whereas swelling index (-0.1937) had negative direct effect on seed size. The detail has been given in (Table. 6).

Indirect effects on seed size or test weight

Among all the cooking quality parameters studied seed size reported maximum positive indirect effect with cooking time (0.9764), followed by hydration capacity (0.8298), seed volume (0.6462), swelling capacity (0.3878) and seed density for 100 seed weight (0.0786). Further indirect effect of cooking time on hydration capacity (0.5189), cooking time on seed volume (0.4176), seed density for 100 seed weight on swelling index (0.238), cooking time on swelling capacity (0.2214) and cooking time on seed volume (0.1279) will influence indirect effect for increase in overall seed size or test weight. The details have been given in (Table. 6).

Discussion

The success of breeder in selecting genotypes possessing higher yield and suitable quality parameters lies largely on the existence and exploitation of genetic variability to the fullest extent. Genotypic variations with respective to mean, minimum and maximum rage has been observed within each type/ classes of green chickpea (RGK,WRGK, SPSGK, SSGK and HSSGK) were significant for most of the parameters studied, indicating that the genotypes included in this study represented considerable variability for these parameters. In green chickpea it has been observed that both Kabuli green type and chinoli (Desi green type) because of significant amount of variation particularly for seed size or test weight. Though there is large genotypic variation for seed size between each type in the green chick pea, the consumers' preference for seed size is different for these two types due to the variation in their uses.

Globally, the Desi and Kabuli types account for about 80 and 20% of chickpea production, respectively. The bulk of chickpea consumption is in the form of splits (dal) and flour (besan), and these are primarily made from the Desi type. For this reason, small to medium seed size (16–24 g/100 seed) is preferred in the Desi type. There is very little demand for large-seeded Desi chickpea. On the other hand, large seed size (30–60 g/100 seed) is preferred in Kabuli types, which are largely used as whole grains in salads, vegetable curries and other preparations. In general, large-seeded Kabuli chickpeas fetch a higher price than small and medium-seeded Kabuli chickpeas, and the price premium increases as the seed size increases (Gaur *et al*., 2007) [9]. Therefore as the green chickpea is of cross between MNK-1 and GKB-10, the advance population which are obtained from these cross will going to satisfies both type of consumer preference, as these populations/ lines will have both kabuli type and chinoli (small) type with an attractive green colour. Seed volume, swelling capacity and cooking time are important traits for consumers, particularly when whole grains are consumed after soaking and cooking. Physicochemical characteristics such as water-absorbing capacity of the seed have been reported to be determined by cell wall structure, composition and compactness of the cells (Muller, 1967) [22]. It may also be related to increased permeability and softer seed-coat.

Seed size (100-seed weight and volume) is an important attribute that determine the consumer preference and cooking quality of chickpea cultivars. The results for seed size exhibited a significant positive correlation with hydration capacity, hydration index, swelling capacity, seed volume and cooking time for all classes of green chickpea genotypes under study and high correlation among them indicated that amount and degree to which water was imbibed by the seed during a period of about 18 hours (overnight) as may be expected. Most of the earlier studies have reported a positive relationship between seed weight and hydration capacity (Williams *et al*., 1983; Singh *et al*., 1992; Gil *et al*., 1996; Kaur *et al*., 2005; Iqbal *et al*., 2006; Khattak *et al*., 2006; Nizakat *et al*., 2006; Ozer *et al*., 2010; Malik *et al*., 2010) [39, 31, 12, 17, 14, 18, 23, 24, 19]. There are also reports on the positive correlation of seed weight with seed volume (Malik *et al*., 2010) [19] and swelling capacity (Gil *et al*., 1996; Kaur *et al*., 2005; Malik *et al*., 2010; Williams *et al*. 1983) [12, 17, 19] and insignificant association of seed size with swelling index and seed density for 100 seed weight suggested that the mechanism of water absorption was only slightly related to seed size, and more closely associated with permeability and water absorption by starch and seed-coat components, (Ozer *et al*. 2010) [24]. Hydration capacity was positively correlated with swelling index, swelling capacity, cooking time, seed size and seed volume; swelling capacity was positively correlated with swelling index, seed density, cooking time and seed volume. There are earlier reports on the positive associations between seed volume and swelling capacity (Khattak *et al*., 2006; Nizakat *et al*., 2006; Malik *et al*., 2011) [18, 23, 20], swelling capacity and hydration capacity (Kaur *et al*., 2005; Ozer *et al*., 2010) [17, 24], and between the swelling index and hydration capacity (Ozer *et al*., 2010) [24]. However seed volume exhibited insignificant correlation with swelling index and seed density for 100 seed weight, these findings were in contradiction with the results of Pandey *et al*. (2007) [25] and this might due to the use of different genotypes.

Cooking time is one of the most important traits for every household as fast cooking varieties can significantly lead to saving of time and energy. It has been observed that genotypic variability for cooking time was very high in the all classes of green chickpea with a minimum to maximum (55.00–72.00 min) with a mean value of 59.66 minutes. Cooking time also shows a significant correlation with the other cooking quality parameters like, seed size or test weight, seed volume, swelling capacity and hydration capacity; same results were observed by Kaur *et al*. (2005) [17]. The longer cooking time can be attributed to the hardness of the seed, the chemical composition of the cell wall and the time taken for starch gelatinization (Jood *et al*., 1998) [15]. The results of this study suggest that it is possible to develop fast cooking varieties for all the classes of green chickpea and in all size categories. Chickpea with large seed and faster cooking time would be very well appreciated by women (both for urban/ working and rural) and can be marketed as a ready-to-eat food. This would increase the demand and act as an incentive to the farmer to grow chickpea.

Table 3: ANOVAs for cooking quality traits of green seeded chickpea genotypes.

SV	DF	HC	SC	SI	SD	SV	SZ	CT
Block (Eliminating checks + Gen.)	5	0.002	0.006	0.01	0.21	11.367	6.652	0.741
Entries(Ignoring blocks)	93	0.014**	0.01	0.03	1.562**	66.730**	94.840**	22.353**
Checks	3	0.256**	0.125**	0.01	1.462*	1099.667**	1590.047**	316.820**
Genotypes	89	0.003	0.004	0.05	1.579**	26.402	36.520**	10.885**
checks Vs Genotypes	1	0.200**	0.183**	0.02	0.389	557.062**	799.706**	159.653**
Error	15	0.002	0.008	0.4	0.4	18.5	10.697	1.253

****** = Significant @ 1 per cent ***** = Significant @ 5 per cent,

Note: HC = Hydration capacity (g/ seed)**;** SC=Swelling capacity (ml/ seed)**;** SI = Swelling index (ml/ seed)**;** SD = Seed density for 100 seed weight (g/ml)**;** SV = Seed volume (ml/100 seeds)**;** SZ = Test weight or seed size (g)**;** CT = Cooking time (min.)

Table 4: Range of cooking quality parameters for green seeded chickpea genotypes.

Parameters	Range		
	Min.	Max.	Mean
HC	0.07	0.78	0.26
SC	0.09	0.75	0.263
SI	0.01	0.13	0.02
SD	1.30	8.10	1.80
SV	3.00	47.00	17.55
TW/SZ	15.00	64.80	27.12
CT	55.00	72.00	59.66

Note: HC = Hydration capacity (g/ seed)**;** SC= Swelling capacity (ml/ seed)**;** SI = Swelling index (ml/ seed)**;** SD = Seed density for 100 seed weight (g/ml)**;** SV = Seed volume (ml/100 seeds)**;** (SZ/TW) = Seed size or Test weight (g); CT = Cooking time (min.)

Table 5: Estimation of phenotypic correlation coefficient for cooking quality parameters of green seeded chickpea genotypes

Parameters	HC	SC	SI	SD	SV	CT	SZ
HC	**1**	0.466**	0.011	0.169	0.450**	0.776**	0.829**
SC		**1**	0.506**	0.339**	0.136	0.331**	0.387**
SI			**1**	0.889**	-0.589**	-0.121	-0.114
SD				**1**	-0.610**	0.085	0.078
SV					**1**	0.624**	0.646**
CT						**1**	0.976**
SZ							**1**

r = 0.2061 @ 0.05% (*); 0.2687 @ 0.01% (**)

Note: HC = Hydration capacity (g/ seed); SC= Swelling capacity (ml/ seed)**;** SI = Swelling index (ml/ seed)**;** SD = Seed density for 100 seed weight (g/ml)**;** SV = Seed volume (ml/100 seeds)**;** (SZ/TW) = Seed size or Test weight (g); CT = Cooking time (min.)

Table 6: Direct and indirect effects of cooking quality parameters on seed size or test weight at phenotypic level (Path diagram is given on Fig.1)

Parameters	HC	SC	SI	SD	SV	CT	SZ	DE
HC		0.0639	0.0015	0.0233	0.0618	0.1064	0.1138	0.1371
SC	0.0382		0.0416	0.0278	0.0112	0.0272	0.1138	0.082
SI	-0.0022	-0.0982		-0.1722	0.1143	0.0235	0.1138	-0.1937
SD	0.0454	0.0907	0.238		-0.1634	0.0229	0.1138	0.2677
SV	0.0923	0.0279	-0.1208	-0.125		0.1279	0.1138	0.2048
CT	0.5189	0.2214	-0.0813	0.0571	0.4176		0.1138	0.6685
SZ	0.8298	0.3878	-0.1147	0.0786	0.6462	0.9764		0.1138

****** =>Significant @ 0.01; Phenotypic residual value = 0.1617

Note: HC = Hydration capacity (g/ seed)**;** SC= Swelling capacity (ml/ seed)**;** SI = Swelling index (ml/ seed); SD = Seed density for 100 seed weight (g/ml)**;** SV = Seed volume (ml/100 seeds)**;** SZ = Seed size or Test weight (g); CT = Cooking time (min.)**;** DE= Direct effect

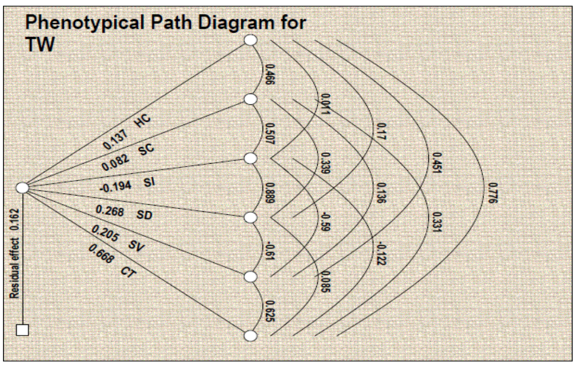

Fig 1: Path diagram indicating direct and indirect effect of cooking quality parameters on seed size or test weight for green chickpea genotypes.

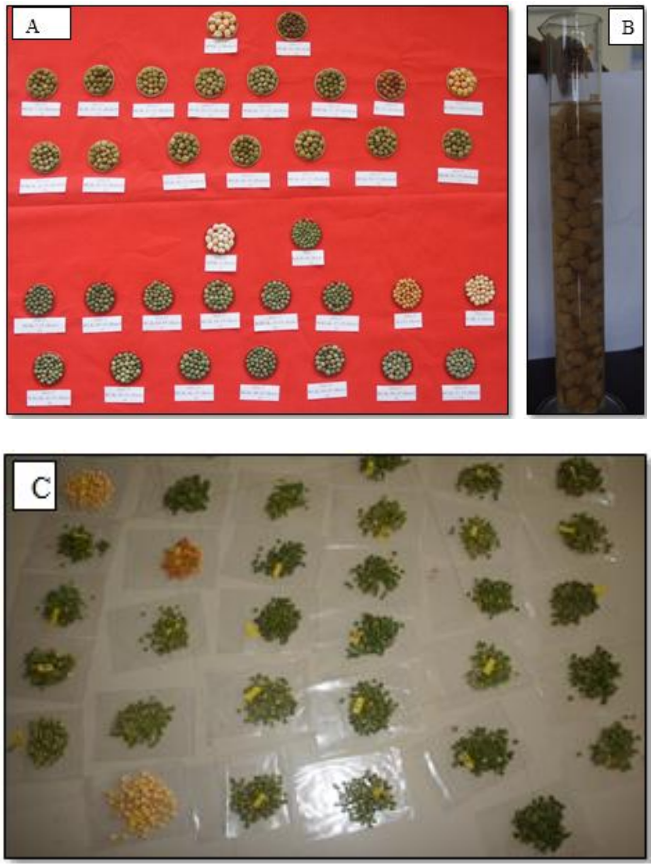

Fig 2: A, B and **C** are the picture/ photographs taken during research work, **A)** comparison of green chickpea genotypes after cooking and before cooking along with the parents and cheks; **B)** Volumetric flask is used to measure seed volume, seed size, hydration capacity and swelling index before and after cooking; **C)** different samples of green seeded chickpea genotypes used in this study.

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