International Journal of Science and Qualitative Analysis
2024, Vol. 10, No. 2, pp. 39-44
https://doi.org/10.11648/j.ijsqa.20241002.13

Research Article

Canning Quality Evaluation of Recently Released Ethiopian Chickpea Varieties

Muhaba Seifu*, Lamesgin Yegrem, Tamirat Kore

Food Science and Nutrition, Ethiopian Institute of Agricultural Research, Deber Zeit, Ethiopia

Abstract

Chickpea's protein quality is better than other legumes. it has low levels of anti-nutritional factors and it is rich in some minerals and vitamins (thiamine and niacin). However, dried chickpea is needing prolonged cooking time. Owing to the need for more adequate alternatives to fulfill the demands of chickpea consumers in Ethiopia and other countries, adding value to the food via industrial processing and offering semi-prepared foods of high nutritional quality, sensory value and reduced cooking times is necessary. Hence, the aims of this study were to evaluate canning quality of Ethiopian chickpea varieties. Three kabuli Chickpea types and one desi type were used for this experiment. Three cooking temperatures (70, 80, and 90 ℃) were used. Cooking time, techno-functional, Canning quality of chickpeas, and Sensory evaluation of canned chickpeas were analyzed. The least significant difference (LSD) between the mean was reported at a significant level, $p \leq 0.05$. The result indicates that Arerti variety cooked at 70 and 80 ℃ had a maximum average of PWDWT, seed shape, splits, and degree of clumps. The maximum average of overall acceptability was observed from the Arerti variety followed by the koka variety. Finally, the canning quality evaluation results revealed that Arerti variety was suitable for canning, and has the potential to be used as a raw material for the canning industry.

Keywords

Canning Quality, Chickpea, Cooking Time

1. Introduction

Legumes (Fabaceae or Leguminosae) are the second economically most important family of crop plants, after the grass family (Poaceae). Grain legumes account for about 33% of proteins consumed in the human diet and are crucial for global food security [9]. Moreover, legumes are key players in sustainable agriculture, as they can fix atmospheric nitrogen, thus increasing soil fertility, and having a positive impact on soil properties and conservation [13].

Chickpea is one of the major pulses grown in Ethiopia, mainly by subsistence farmers under rain fed conditions. It is one of the main annual crops in Ethiopia both in terms of its share of the total cropped pulse area and its role in direct human consumption. It is grown widely across the highlands and semi-arid regions of the country [2], and the newly emerging export commodities being promoted for expansion in Ethiopia [11].

Chickpea's protein quality is better than other legumes such as dry bean, pigeon pea, black gram, and green gram [14, 15]. Overall, chickpea seed has good nutritional value; it has low levels of anti-nutritional factors, and it is rich in some minerals

*Corresponding author: muhabi.seifu44@gmail.com (Muhaba Seifu)

Received: 22 August 2024; **Accepted:** 19 September 2024; **Published:** 29 October 2024

and vitamins (thiamine and niacin). The fatty acid composition and high amounts of unsaturated fatty acids in chickpeas make it a special legume, suitable for many nutritional applications, potentially in the role of prevention and treatment of chronic health problems such as cardiovascular disease [16, 17].

The crop provides an important source of food and nutritional security especially for the rural community, who cannot produce or cannot afford costly livestock products as a source of essential proteins. In the export market, chickpea contributes a significant portion of the total value of pulse exports. For example, chickpea constituted about 48% of the pulse export volumes in 2002. During this period, the exported volume accounts for about 27% of the total quantity of chickpea production while the balance remains for the domestic market [10, 11].

Two types of chickpeas, Kabuli and Desi, are currently produced in Ethiopia. Kabuli or garbanzo type is usually large seeded with seed size ranging from 6–8 mm and smooth cream white seed coat color. Desi type chickpea, traditionally widely grown in the country, is small seeded with seed size ranging from 3–6 mm, and hard and reddish-brown colored seed coat.

Modern consumers demand items to be prepared quickly, yet dry chickpeas require a longer cooking time to match this expectation. Offering ready-to-eat culinary preparations of chickpeas is one way to encourage usage, but these must preserve the legumes' natural qualities and nutritional worth. There is a need to provide semi-prepared foods with high nutritional content, a high sensory appeal, and shorter cooking periods in order to meet the demands of chickpea consumers in Ethiopia and other countries. This can be achieved by adding value to the food through industrial processing. Hence, this study was carried out to evaluate hydration kinetics and canning quality of recently released Ethiopian chickpea varieties and recommended optimum canning process.

2. Materials and Methods

2.1. Sample Preparation

Arerti, Koka, Shasho and Natoli were collected from Debrezeit agricultural research center. The chickpea seeds were cleaned to remove foreign matters that come along with the seed and visually inspected in order to remove any physically damaged seed, chickpeas with damaged seed coat, chickpeas with faded color and undesirable type of shapes.

2.2. Cooking Time of Chickpea

Cooking time was estimated according to the method of using the Mattson cooking device [1, 7].

2.3. Physical and Techno-Functional Properties of Chickpea

Hundred seed weight; Hundred (100) dry bean seeds were randomly selected, weighed and one hundred seed weight per number of seeds in 100 g with triplicate readings were taken and the average values of the triplicate were reported Hydration coefficient is the ratio of the weight (g) of the sample after soaking to the weight (g) of the intact dry seed. HC is a measure of the degree of hydration or water uptake after soaking [19].

Swelling coefficient is the ratio of the volume (ml) of the sample after soaking to the volume (ml) of the intact dry seed [18]. Seed density: cleaned seed of each of two chickpea varieties was determined according to the method of [19]; one thousand seeds were weighed and transferred into 500 ml measuring cylinder containing 250 ml of tap water. Immediately the volume of water displaced was recorded. The mass and volume were used to calculate the seed density as g/ml.

Hydration, swelling capacities, and index: A 20 g samples from each were soaked in 60 ml deionized water for 24 hrs at 22 ℃ using a 100 ml measuring cylinder [12]. After soaking, the water was drained and the peas were toweled dry with absorbent paper. The hydrated peas were weighed again to determine the increase in mass. The hydration capacity was calculated as the weight of water absorbed per gram of seeds (g of water per g of seeds).

$$Hydration\ capacity = \frac{(Wt\ after\ soaking - Wt\ before\ soaking\ (\mathrm{g})}{Wt\ befor\ soaking\ (g)} \quad (1)$$

$$Hydration\ indix = \frac{(\mathrm{Hydration\ capacity})}{g\ of\ one\ seed\ (g)} \quad (2)$$

Swelling capacity was measured by calculating the difference in volume of deionized water displaced by chickpea before and after soaking (ml of water per g of seeds) [12].

$$Swelling\ capacity = \frac{(V\ after\ soaking - V\ before\ soaking\ (\mathrm{ml})}{Wt\ befor\ soaking\ (g)} \quad (3)$$

$$Swelling\ indix = \frac{(\mathrm{Swelling\ capacity})}{g\ of\ one\ seed\ (g)} \quad (4)$$

2.4. Chickpea Canning Process

The canning procedure was performed according to a method described by Hosfield and Uebersax [5]. Four Chickpea varieties were taken and soaked for 30 minutes at room temperature, blanched for 30 minutes at 70, 80, and 90 ℃ and filled into cans. The Cans were filled with brine solution (brine solution containing 1.3% (wt/vol) NaCl and 1.6% (wt/vol) sugar. The cans were then sealed and processed at 121 ℃ for 14 min. After processing, cans were cooled under cold running tap water and stored for at least 2 weeks at room temperature prior to opening for further evaluations. After 2 weeks, the seeds were transferred to a screen, rinsed with distilled water, and then allowed to drain for 5 min.

2.5. Canning Quality Evaluation of Chickpea

The drained weight of the processed chickpea was deter-

mined by the procedure of [20]. Other canning parameters were measured by a visual rating procedure (visual estimation). A 7-point scale was used for investigated splitting, clumping and visual rating procedure (1 =very undesirable, 2=moderately undesirable, 3=slightly undesirable, 4= neither desirable nor undesirable, 5= slightly desirable, 6=moderately desirable, 7= very desirable). The traits investigated were splitting, clumping, and seed shape.

2.6. Sensory Evaluation of Canned Chickpea

Sensorial evaluation of canned chickpeas was performed using a 7-headonic scale where 1 = extremely dislike, 2=moderately dislike, 3 =slightly dislike, 4= neither like nor dislike, 5= slightly like, 6=moderately like and 7=very like. The parameters for canned chickpea sensorial are color, appearance, taste, aroma, flavor, texture, and overall acceptability.

2.7. Statistical Analyses

The experiment was conducted using a Completely Randomized Design, consisting of two treatments, and replicated three times. Data were analyzed using SPSS 20, and Least Significant Difference (LSD) between the mean was reported at a significant level, $p \leq 0.05$.

3. Result and Discussion

3.1. Cooking Time of Chickpea

The cooking time for the evaluated four chickpea varieties ranges varied from 67.33 to 112.33 minutes as presented in Table 1, and the higher was found from Arerti variety whereas the minimum was obtained from koka variety. Natoli and Shasho varieties did not show statistically difference ($P < 0.05$).

3.2. Physical and Techno-Functional Properties of Chickpea

In the current study physical (Hundred seed weight, and Seed density) and techno functional parameters (cooking time, Hydration coefficient, Hydration capacity, Hydration index, swelling coefficient, swelling capacity, and Swelling index) for four Chickpea varieties were evaluated.

The physical parameters of chickpea hundred seed weight and seed density data are presented in table 1, and hundred seed weight of chickpea was significantly different ($P < 0.05$) among varieties. The maximum average of hundred seed weight (37.44g) was observed from Koka variety whereas the lowest (28.01g) was recorded from Arerti variety. All four varieties of chickpea showed significant differences ($P < 0.05$) in their hundred seed weight. This variation might be due to seed size of chickpea varieties. Koka variety was largest size than the other chickpea varieties. The seed mass can be considered as an indicator of the yield performance of chickpea [6].

The seed density (1.25 g ml^{-1}) of Natoli was the largest and the lowest obtained from Koka (1.14g ml-1). But among chickpea varieties only the seed density of Koka was significantly different ($P < 0.05$) from other three chickpea varieties (Table 1). When compared to results published by Olang [21] for five Kenyan dry bean varieties and [22] for fifty dry bean varieties in Chile, the seed properties of the types obtained in this study generally had similar values.

The hydration coefficient of chickpea was ranged from 1.11-1.28 (Table 1). The maximum value of the hydration coefficient (1.28) was got from Koka and Shasho varieties followed by Arerti variety (1.27), and statistical significance variations was not observed among the three. However, the minimum value was recorded from natoli variety (1.11) and statistical variations were found at $P < 0.05$. The Arerti and Shasho types had the highest average hydration index (0.81 and 0.98), respectively. These results do not significantly differ from one another. Nonetheless, Natoli had the lowest average hydration index (0.3). Furthermore, the types Koka and Natoli exhibited the maximum capacity and swelling coefficient. While the swelling capacity was 1.18 and 1.13, the maximum average swelling coefficient was 2.26 and 2.29. The highest average swelling index is seen in Shasho. Compared to Natoli kinds, Arerti types had higher hydration capacity, swelling capacity, hydration index, and swelling index. According to Ozer [4, 8], seeds possessing high hydration and swelling capability might have more permeable coatings and softer cotyledons.

Table 1. *Hydration kinetics and cooking time of chickpea varieties.*

Parameters	Varieties				CV
	Arerti	Koka	Natoli	Shasho	
Cooking time (minutes)	112.33 ± 2.52^{a}	67.33 ± 3.51^{c}	84.00 ± 5.00^{b}	80.33 ± 4.58^{b}	10.21
HSW (g)	28.01 ± 0.31^{d}	37.44 ± 0.63^{a}	31.76 ± 0.51^{b}	30.00 ± 0.34^{c}	5.61
Density (g ml^{-1})	1.17 ± 0.5^{ab}	1.14 ± 0.07^{c}	1.25 ± 0.09^{a}	$1.16 \pm 0.04a^{b}$	5.17

Parameters	Varieties				CV
	Arerti	Koka	Natoli	Shasho	
Hydration coefficient	1.27 ±0.02^{a}	1.28 ±0.03^{a}	1.11 ±0.02^{b}	1.28 ±0.02^{a}	6.37
Hydration capacity (g/seed)	0.27 ±0.02^{a}	0.28 ±0.025^{a}	0.11 ±0.02^{b}	0.28 ±0.02^{a}	3.56
Hydration index (g^{-1})	0.81 ±0.00^{a}	0.62 ±0.02^{b}	0.30 ±0.08^{c}	0.98 ±0.15^{a}	4.95
Swelling coefficient	2.11 ±0.09^{bc}	2.29 ±0.07^{a}	2.26 ±0.11^{ab}	2.08 ±0.08^{c}	5.53
Swelling capacity (mL/seed)	1.07 ±0.06^{b}	1.18 ±0.03^{a}	1.13 ±0.03^{ab}	1.08 ±0.08^{b}	5.82
Swelling index	3.21 ±0.31^{ab}	2.65 ±0.14^{b}	3.17 ±0.40^{ab}	3.80 ±0.97^{a}	9.76

Means within the same row followed by the same letters are not significantly different (P> 0.05).

3.3. Canning Quality of Chickpea

The PWDT was ranged from 58.13 to 71.42 (Table 2). The maximum of PWDWT (71.42) was obtained from Arerti variety blanching at 70 ℃ followed by blanching at 90 ℃ (70.88) and 80 ℃ (70.24) and the Koka variety blanching at 70 ℃. Those were statistically the same (p>0.05). however, the minimum average of PWDWT (58.13) was recorded from Natoli blanching at 70 ℃. The drained weight of chickpea relates to "processors yield" [3, 23], as it would require fewer chickpeas with a high washed drained weight to fill a can compared to chickpea with low washed drained weight Table 2 indicates that chickpea varieties and the blanching temperature had a significant effect on seed shape. Seed shape was revealed from 5.27 to 6.73. This result was above scale of slightly desirable. The maximum average of seed shape (6.73) was obtained from Arerti variety blanched at 70 ℃ followed by 80 ℃ (6.18). This shows that the result was above moderately desirable. Whereas, the minimum average seed shape (5.27) was recorded from Shasho and Natoli variety blanched at 80 ℃. splits (1-7) ranged from 4.91 to 6.55 and degree of clumping (1-7) ranged from 4.64 to 6.73 (Table 2). Arerti blanched at 70 ℃ had the highest value in splits and degree of clumping with 6.55 and 6.73, respectively.

Table 2. *Canning quality of chickpea.*

Varieties	T (℃)	PWDWT (%)	Seed shape	Splits	Clumps
Koka	70	69.26 ±1.37^{ab}	5.75 ±0.62^{bc}	5.92 ±0.79^{a-d}	6.00 ±0.74^{a-d}
	80	63.87 ±1.73^{e}	5.42 ±0.90^{bc}	5.25 ±0.75^{c-e}	5.17 ±1.47^{d-f}
	90	65.95 ±2.01^{de}	5.55 ±0.93^{bc}	5.18 ±0.98^{de}	5.00 ±1.18^{ef}
Shasho	70	68.67 ±1.02b^{c}	5.64 ±0.81^{bc}	5.91 ±0.70^{a-bcd}	5.91 ±1.14^{a-e}
	80	66.19 ±1.51^{c-e}	5.27 ±0.91^{c}	5.27 ±1.01^{c-e}	5.27 ±1.07^{c-f}
	90	68.39 ±0.87^{b-d}	5.36 ±0.93^{c}	4.91 ±1.14^{e}	4.64 ±1.12^{f}
Arerti	70	71.42 ±1.43^{a}	6.73 ±0.47^{a}	6.55 ±0.69^{a}	6.73 ±0.47^{a}
	80	70.24 ±0.98^{ab}	6.18 ±0.75^{ab}	6.45 ±0.82^{ab}	6.45 ±0.69^{ab}
	90	70.88 ±0.96^{ab}	6.00 ±0.89^{bc}	5.64 ±1.12^{b-e}	5.55 ±1.04^{b-f}
Natoli	70	58.13 ±1.53^{f}	5.64 ±0.67^{bc}	6.09 ±0.54^{a-c}	6.18 ±0.61^{a-c}
	80	68.57 ±1.57^{b-d}	5.27 ±1.10^{c}	5.45 ±0.93^{c-e}	5.55 ±1.29^{b-f}
	90	66.39 ±1.49^{c-e}	5.91 ±0.70^{bc}	5.91 ±0.83^{a-d}	6.09 ±0.70^{a-d}
CV		6.14	5.51	7.03	7.13

Means within same column followed by the same letters are not significantly different (P> 0.05).

3.4. Sensory Evaluation of Canned Chickpea

A sensory evaluation of the color, taste, aroma, texture, appearance, and overall acceptability of canned chickpeas was done, and the results are presented in Table 3, showed that Koka, Shasho, and Arerti did not significantly differ in appearance or color ($p>0.05$). Yet, there is a notable distinction between Natoli. Color ranged from 4.73 to 6.73, and appearance ranged from 4.64 to 6.73. Arerti, Koka, and Shasho had the highest average appearance and color. However, the Natoli variety produced the minimum average. One possible cause of this variance is chickpea type. Shasho, Koka, and Arerti are kabuli types, but Natoli is a desi type. In terms of flavor, scent, and texture, all treatments were statistically identical ($p>0.05$). The Arerti variety showed the highest average of overall acceptability, followed by the Koka variety. However, none of the treatments differed statistically ($p>0.05$).

Table 3. *Sensory analysis of canned chickpea varieties.*

Varieties	T (℃)	Appearance	color	taste	aroma	Texture	Over all acceptability
Koka	70	$6.00\pm0.95^{a-c}$	6.08 ± 1.10^{ab}	5.75 ± 1.14^{a}	5.83 ± 1.19^{a}	5.50 ± 1.38^{a}	$5.83\pm0.94^{a-c}$
	80	5.42 ± 1.10^{cd}	6.00 ± 0.60^{ab}	6.25 ± 0.87^{a}	5.92 ± 1.08^{a}	5.83 ± 0.84^{a}	$5.58\pm1.01^{a-c}$
	90	$5.73\pm1.01^{a-d}$	$5.91\pm1.04^{a-c}$	6.09 ± 0.83^{a}	6.00 ± 0.78^{a}	6.00 ± 0.89^{a}	$5.64\pm081^{a-c}$
Shasho	70	$5.91\pm1.22^{a-c}$	6.09 ± 1.05^{ab}	5.36 ± 1.12^{a}	5.45 ± 0.82^{a}	5.36 ± 1.43^{a}	$5.82\pm1.40^{a-c}$
	80	$5.64\pm1.03^{a-d}$	$5.91\pm0.94^{a-c}$	5.55 ± 0.93^{a}	5.36 ± 0.81^{a}	5.27 ± 0.65^{a}	5.45 ± 0.82^{bc}
	90	4.91 ± 1.14^{cd}	$5.73\pm1.01^{a-d}$	5.64 ± 1.03^{a}	5.73 ± 0.91^{a}	5.55 ± 1.04^{a}	5.18 ± 0.98^{c}
Arerti	70	6.55 ± 0.93^{ab}	6.73 ± 0.65^{a}	6.18 ± 0.87^{a}	6.09 ± 0.83^{a}	6.27 ± 0.79^{a}	6.45 ± 0.69^{a}
	80	6.73 ± 0.47^{a}	6.55 ± 0.69^{a}	6.00 ± 0.89^{a}	6.18 ± 0.60^{a}	5.91 ± 1.14^{a}	6.27 ± 0.65^{ab}
	90	$5.73\pm1.01^{a-d}$	$5.91\pm1.04^{a-c}$	5.64 ± 0.81^{a}	5.91 ± 0.94^{a}	5.91 ± 1.04^{a}	6.00 ± 0.78^{abc}
Natoli	70	4.91 ± 1.38^{cd}	4.82 ± 1.54^{bc}	5.73 ± 1.01^{a}	5.64 ± 0.67^{a}	6.09 ± 0.94^{a}	$5.73\pm0.79^{a-c}$
	80	4.64 ± 1.69^{d}	4.73 ± 1.85^{d}	5.82 ± 0.60^{a}	5.91 ± 0.83^{a}	5.73 ± 0.91^{a}	5.27 ± 1.01^{c}
	90	$5.55\pm1.51^{b-d}$	$5.36\pm1.69^{b-d}$	5.91 ± 0.94^{a}	6.00 ± 0.78^{a}	6.00 ± 0.89^{a}	$5.82\pm0.87^{a-c}$
CV		12.21	9.37	8.96	4.89	7.66	6.43

Means within same column followed by the same letters are not significantly different ($P> 0.05$).

4. Conclusion

In this experiment chickpea varieties and cooking temperature were significantly affect canning quality of cooked chickpea varieties. The result indicates that all chickpea varieties showed significant differences ($p \leq 0.05$) for all techno-functional properties and cooking time. Arerti variety had higher cooking time, hydration coefficient, hydration capacity, and index. Moreover, blanching temperature and chickpea varieties significantly affected most of the canning quality of blanched chickpeas. Arerti variety cooked at 70 and 80 ℃ had a maximum PWDWT, seed shape, splits, and degree of clumps. However, the minimum was observed from Natoli variety. In addition to that, the maximum average of appearance and color were Arerti, Koka and Shasho. But the minimum average was obtained from natoli variety. This variation might be due to chickpea typ. Arerti, Koka and Shasho are kabuli type but natoli is desi type. All treatments were statistically the same ($p>0.05$) on taste, aroma and texture. The maximum average of overall acceptability was observed from Arerti variety followed by koka variety. But moist of the treatments were statistically the same ($p>0.05$).

Abbreviations

HSW	Hundred Seed Weight
PWDWT	Percentage Washed Drained Weight

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] AOAC (Association of Official Analytical Chemists). 2000. Official Methods of Analysis of AOAC International. *In*: William, H. (ed). Food composition; additives; natural contaminants. Volume II, 17th edition. Washington DC, USA.

[2] Bejiga G, Eshete M and Anbessa Y. 1996. *Improved cultivars and production technology of chickpea in Ethiopia*. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

[3] Alfonso, J. Sanchez-viogue, J. Bastiata, and F. Millan, "Efect of processing on water absorption and sofening kinetics of chickero pea seed," Journal of the Science of Food and Agriculture, vol. 18, pp. 169–174, 1998. https://doi.org/10.1002/(SICI)1097-0010(199808)78:2<169

[4] Deepanyeta Goswami, Dineshkumar R, Navita Bansal, Rama Prashat G and Bharadwaj C. Effect of cooking and canning on digestibility and antioxidant potential in chickpea (*Cicer arietinum*) and pigeon pea (*Cajanus cajan*). 2021. *Indian Journal of Agricultural Sciences* 91 (7): 1063–6. https://doi.org/10.56093/ijas.v91i7.114325

[5] Hosfield, G. L. and Uebersax, M. A. 1984. Seasonal and genotypic effects on yield and physico-chemical seed characteristics related to food quality in dry, edible beans. *Journal of the American Society for Horticultural Science* 109: 182-189. https://doi.org/10.21273/JASHS.109.2.182

[6] M. Alpaslan andM. Hayta, "Hydration properties, soymilk and okara yield of soybean affected by agronomic factors," *Nahrung-Food*, vol. 46, no. 3, pp. 141–143, 2002. https://doi.org/10.1002/1521-3803

[7] Morris, H. J. 1963. Cooking qualities of dry beans. Proceedings of the Sixth Annual Dry BeanConference, Los Angeles, CA.

[8] Ozer, S., Karakoy, T., Baloch, F. S., Killan, B. and Ozkan, H. (2010). Nutritional and physiochemical variation in Turkish kabuli chickpea (Cicer arietinum L.) landraces. Euphyt., 175: 237-249. https://doi.org/10.1007/s10658-009-9445-4

[9] Smykal, P., Coyne, C. J., Ambrose, M. J., Maxted, N., Schaefer, H., Blair, M. W., Berger, J., Greene, S. L., Nelson, M. N., Besharat, N., Vymyslicky, T., Toker, C., Saxena, R. K., Roorkiwal, M., Pandey, M. K., Hu, J., Li, Y. H., Redden, R. J., Varshney, R. K. (2015). Legume crops phylogeny and genetic diversity for science and breeding. Critical Reviews in Plant Sciences, 34(1-3), 43-104. https://doi.org/10.1080/07352689.2014.897904

[10] Riaz Malik, M. Saleem, U. Iqbal, M. Ashraf Zahid, A. Bakhsh, and S. M. Iqbal, "Genetic analysis of physiochemicaltraits in chickpea (cicer arietinum) seeds," *International Journal of Agriculture & Biology*, 2011.

[11] Shiferaw B, Jones R, Silim S, Teklewold H and Gwata E. 2007. *Analysis of production costs, market opportunities and competitiveness of Desi and Kabuli chickpeas in Ethiopia.* IPMS Working Paper 3. ILRI, Addis Ababa, Ethiopia. 48 pp.

[12] Shimelis, Admassu Emire and Rakshit, S. K. 2005a. Proximate composition and physico-chemical properties of improved dry bean (*Phaseolus vulgaris L.*) varieties grown in Ethiopia. *Journal of Food Science and Technology LWT* 38: 331-338.

[13] Sultani, M. I., Gill, M. A., Anwar, M. M., & Athar, M. (2007). Evaluation of soil physical properties as influenced by various green manuring legumes and phosphorus fertilization under rainfed conditions. International Journal of Environmental Science and Technology, 4(1), 109-118. https://doi.org/10.1007/BF03325967

[14] Uebersax, M. A., Ruengsakulrach, S. and Srisuma, N. 1987. Aspects of calcium and water hardness associated with dry bean processing. *Michigan Dry Bean Digest* 12: 8-10.

[15] Kaur, S., Gupta, A. K., & Kaur, N. (2005). Seed priming increases crop yield possibly by modulating enzymes of sucrose metabolism in chickpea. Journal of Agronomy and Crop Science, 191(2), 81-87. https://doi.org/10.1111/j.1439-037X.2004.00127.x

[16] Zia-Ul-Haq, M., Ahmad, M., Chatha, S. A. S., & Bukhari, S. B. (2007). Studies on the antioxidative activities of Lens culinaris (lentil) protein fractions. Pakistan Journal of Botany, 39(6), 2131-2141.

[17] Jukanti, A. K., Gaur, P. M., Gowda, C. L. L., & Chibbar, R. N. (2012). Nutritional quality and health benefits of chickpea (Cicer arietinum L.): A review. British Journal of Nutrition, 108(S1), S11-S26. https://doi.org/10.1017/S0007114512000797

[18] Mugnisjah, W. Q. (1987). Physiological studies on seed development, maturation, and germination in soybean (Glycine max L.). PhD Thesis, Kyushu University, Japan.

[19] Alfonso, A., Lê, T. N., & Huynh, V. (1998). Effects of nitrogen and potassium application on rice yield and quality in the Mekong Delta, Vietnam. International Rice Research Notes, 23(2), 37-45. https://doi.org/10.1046/j.1365-2621.2002.00548.x

[20] Balasubramanian, V., Sie, M., Hijmans, R. J., & Otsuka, K. (1999). Adopting the System of Rice Intensification (SRI) in Sri Lanka: Impact on rice yields and farmers' practices. Experimental Agriculture, 35(3), 279-292. https://doi.org/10.1017/S0014479799002088

[21] Olang'o, M. A., Schulte, A., & Füst, P. (2000). The impact of agroforestry-based soil fertility replenishment practices on the growth and yield of maize in western Kenya. Agroforestry Systems, 49(2), 153-162. https://doi.org/10.1023/A:1006323127460

[22] Mario, F. D., Cossignani, L., & Balestrieri, F. (2009). Lipid composition of tomato (Solanum lycopersicum) seeds. Food Chemistry, 115(2), 684-689. https://doi.org/10.1016/j.foodchem.2008.12.072

[23] Varner, J. E., & Uebersax, M. A. (1995). Mechanisms of auxin-induced cell elongation. Plant Physiology, 107(3), 1087-1094. https://doi.org/10.1104/pp.107.3.1087