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Functional properties and cooking quality of Kidney beans (*Phaseolus vulgaris* L.) grown in different regions of Himachal Pradesh

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Abstract

Legumes are an essential component of our diet especially in developing world; they are widely grown and consumed in various regions, and excellent sources of proteins and complex carbohydrates. Six kidney bean varieties were evaluated for their functional and cooking properties. Samples of kidney beans used in present study were procured from Mountain Agriculture Research and Extension Centre, Sangla (Kinnaur) of Himachal Pradesh, India. The bulk density of the kidney beans varied between 0.76 g/ml to 0.81 g/ml. Higher bulk density was found in variety Jwala (0.86 g/ml) whereas, lowest was found in Baspa, Him1 and Triloki varieties (0.76 g/ml). Hydration capacity and swelling capacity of the seeds of different varieties varied significantly and present in the range of 0.21–0.46 g/seed and 0.22–0.35 ml/seed, respectively. The swelling capacity of variety Triloki was higher as compared to other varieties of kidney beans. Cooking time of unsoaked seeds of different varieties significantly varied and ranged between 25 to 35 min. whereas, the soaking of grains of kidney beans reduced the cooking time and varied from 15 to 20 min.

Key words: Kidney beans, functional properties, cooking quality, cooking time.

Legumes gained popularity in Indian diets and are important food source and play a significant role in traditional recipes. Legumes, belong to the *leguminaceae* family are produced and consumed widely throughout the world, particularly in tropical and sub tropical areas of Africa, Asia and Latin America (Barampama & Simard, 1995). During 2017-18, pulses were cultivated over > 29 million ha (Mha) of area and recorded the highest ever production of 25.23 million tonnes (Mt) at a productivity level of 841 kg/ha. The exponential growth rate in production of pulses during last year was >9 per cent. (DES, Ministry of Agriculture & Farmers Welfare GOI, 2018-2019). Among the pulses, kidney bean (*Phaseolus vulgaris* L.) is the most widely produced and consumed in the world and has an important place in human nutrition. Legumes are widely grown and consumed in various regions and are excellent sources of proteins, complex carbohydrates and fairly good sources of minerals, vitamins and polyunsaturated fatty acids (Hudson, 1994). The importance of legume seeds as food and functional ingredients has stimulated much attention to their utilization. They have been used by food industries as ingredients and as supplements in various food products for many years. For successful use in food applications, they should possess several desirable characteristics such as functional properties. Among the different treatments, heat treatment of pulses involving cooking and roasting are used to remove anti-nutritional factors (Gujral *et al*., 2013). Cooking is the common processing method applied to remove anti-nutritional factors and to ensure acceptable sensory quality of pulses (Klamczynska *et al*., 2001; Satya *et al*., 2010).

Prior to cooking, pulses are usually soaked in water from few hours to overnight in order to save time and energy to cook (Fernandes *et al*., 2010). 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 (Wani *et al.,*

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2013 and Vindiola *et al*., 1986).

Factors affecting cooking quality of pulses include cultivar, seed/ grain characteristics, composition, growing location and environment (Bishnoi & Khetarpaul, 1993 and Gubbels & Ali-Khan, 1991). Physical properties, such as size and weight, as well as seed coat and cotyledon characteristics, influence pulse cooking quality (Sefa-Dedeh & Stanley, 1979).

Keeping in view the importance of the kidney beans the present study was planned to analyze the functional properties and cooking quality of Kidney beans (*Phaseolus vulgaris* L.) grown in different regions of Himachal Pradesh.

Materials and Methods

Certified seeds/ grains of six kidney bean varieties (*Kanchan, Jwala, Baspa, Him 1, Triloki* and *Chamba Landrace*) were procured from Mountain Agriculture Research and Extension Centre, Sangla, district Kinnaur region of Himachal Pradesh, India. Seeds were cleaned to remove the dirt, foreign and other materials and stored in air tight container and in dark place for further use at room temperature. Then, the seeds were grounded into fine powder with the help of Philips mixer- cum- grinder and sieved with 150 micron mesh to get fine uniform particles and stored in airtight containers. All the reagents used in the study were of analytical grade. All the analysis was carried out in triplicate.

Functional properties

Bulk Density (Grains and flour)

The kidney bean grains and flour were filled separately in measuring cylinders up to certain level from the constant height followed by weighing. (Narain *et al*. 1978).

True Density

True density is the density of the solid material excluding the volume of any open and closed pores. The true density was measured by toluene displacement method. One thousand grains of millets were weighed and put in graduated cylinder contain known amount of toluene and rise in toluene level was noted. (Mohsenin 1980).

Porosity

Porosity is defined as the volume fraction of the air or the void fraction in the sample. Porosity was analyzed by using the relationship of bulk density and true density (Mohsenin 1970; Nimkar and Chattopadhyay 2001).

Porosity is calculated by true density subtracted by bulk density, their result divided by true density and whole result multiplied by 100.

Porosity =

(True density – Bulk density)/ True density x 100

Angle of repose

Angle of repose was measured by dropping kidney bean seeds on plain surface at height of about 30 cm, which results in a conical pile. Then with the help of scale length of the base of pile and height of pile was measured. By putting values of length of base and height in the below mentioned formula angle of repose of seeds was calculated:

$\theta = \tan^{-1}$ (2 height/base)

Water and oil absorption

Water absorption was measured by the centrifugation method by Sathe and Salunkhe (1981). The sample (1.0 g) was dispersed in 25 ml of distilled water and placed in pre-weighed centrifuge tubes. The dispersions were stirred after intervals of 5 min, held for 30 min, followed by Remi Doctor, R-303, centrifugation for 25 min at 3000 rpm. The supernatant was decanted, excess moisture was removed by draining for 25 min at 50°C, and then the sample was reweighed.

Emulsion stability

Emulsion stability (ES) was determined by the method of Yasumatsu *et al.* (1972). An emulsion of 1g flour sample, 10 ml of water and 10 ml soybean oil was prepared in calibrated centrifuge tube. That emulsion in the centrifuge tube was initially heated in water bath (80° C) for 30 min and subsequently cooled for 15 min. under tap water before centrifugation. The emulsion was centrifuged at 2000 x g rpm for 10 minutes.The ratio of the height of the emulsion layer to the total height of mixture was calculated as percentage.

Cooking properties

Swelling capacity and swelling index

The volume of 100 g of seeds was predetermined using a graduated cylinder and they were subsequently soaked overnight in distilled water. The volume of the seeds after soaking was then measured. Swelling capacity and the swelling index were determined (Adebowale *et al*. 2005).

Swelling capacity is calculated by volume after soaking subtracted by volume before soaking, their result divided by numbers of seeds.

$$\text{Swelling capacity} = \frac{\text{Volume after soaking} - \text{Volume before soaking}}{\text{Number of seeds}}$$

Swelling index is calculated by the ratio of the swelling capacity of seeds to the volume of one seed.

$$\text{Swelling index} = \frac{\text{Swelling capacity of seeds}}{\text{Volume of one seed}}$$

Hydration capacity and hydration index

100 g seeds were soaked in 100 ml of distilled water in a measuring cylinder and covered with an aluminum foil. Seeds which were left to soak for 24 h in room temperature (20±2°C); drained and excess water was removed using a tissue paper. The weight of the swollen seeds was measured. Hydration capacity and hydration index were calculated (Adebowale *et al*. 2005).

Hydration capacity is calculated by weight after soaking subtracted by weight before soaking, their result divided by numbers of seeds.

$$\text{Hydration capacity} = \frac{\text{Weight after soaking} - \text{Weight before soaking}}{\text{Number of seeds}}$$

Hydration index is calculated by the ratio of the hydration capacity of seeds to the volume of one seed.

$$\text{Hydration index} = \frac{\text{Hydration capacity of seeds}}{\text{Weight of one seed}}$$

Cooking time

Distilled water was brought to boil in 500 ml spout less beakers fitted with bulb condenser to prevent loss of water during cooking. 20 g of seeds from each cultivar was separately added to them. Boiling was continued, and samples (4–5 seeds) were withdrawn using a spatula at 5 min, 10 min, 15 min intervals upto 30 min and thereafter after every 2 min and tested for softness by pressing between finger and thumb. The time from addition of seeds till achievement of the desirable softness was recorded as the cooking time.

Solid gruel loss

The sample was randomly selected from each treatment. 2g of sample was cooked in 20 ml distilled water for minimum cooking time in boiling water bath. The gruel was transferred after several washings to 50 ml volumetric flask and made the volume with distilled water. The leached solid solution, 10 ml of each treatment was kept for drying in three petriplates (70℃) till it got completely dried. The solids were weighed and per cent solid loss in gruel was calculated by using following formula.

Solid loss in gruel is calculated by weight of petridish and sample after drying subtracted by weight of empty petridish which was multiplied by volume made and then whole was divided by the multiplication of weight of sample and aliquot taken.

$$\text{Solid loss in gruel (\%)} = \frac{\text{Wt of petridish and sample after drying (g) - wt of empty petridish (g) x volume made}}{\text{Wt of sample (g) x aliquot taken}}$$

Cooked length–width ratio

The cumulative length and width of 10 seeds were measured after cooking for minimum cooking time. The length–breadth ratio of the 10 cooked seeds was determined by dividing the cumulative length to the cumulative breadth of cooked seeds (Wani *et al.* 2015).

Water uptake ratio

20 g of seeds was cooked in 200 ml of double distilled water for minimum cooking time. The cooked seeds were then removed; drained and surface water on seeds was removed by using filter paper. The samples were weighed and the water uptake ratio was calculated as the ratio of weight gained after cooking to weight before cooking (Hamid *et al*. 2014).

Results and Discussion

Bulk density

The bulk density of Kidney bean varieties viz. *Kanchan, Jwala, Baspa, Him1, Triloki* and *Chamba Landrace* were 0.80, 0.76, 0.81, 0.76, 0.76 and 0.79 g/ml respectively (Table 1). Higher bulk density was found in Jwala variety (0.86 g/ml) whereas, lowest was found in Baspa (0.81g/ml) followed by Him1 and Triloki (0.76 g/ml). Siddiq *et al*. (2009) examined the bulk density of the beans flour varied significantly and varied between from 0.515 g/ml for bean flour to 0.556 g/ml for red kidney bean flour. The difference in the bulk density of different varieties might have been due to more the weight of seeds higher will be the bulk density.

True density

Table 1 depicted the true density values of Kidney bean varieties viz. *Kanchan, Jwala, Baspa, Him1, Triloki* and *Chamba Landrace* as 1.02, 1.12, 1.04, 1.01, 1.00 and 1.02 g/ml respectively. Higher true density was found in Jwala variety (1.12 g/ml) whereas, lowest was found in Triloki variety (1.00 g/ml). Wani *et al.* (2014) observed slightly higher value of true density in the range of 1.22–1.27 kg/l. True density is higher in Jwala variety due to more weight of the Jwala variety.

Table 1. Functional properties of Kidney bean varieties of Himachal Pradesh

Parameters	Varieties						
	Kanchan	Jwala	Baspa	Him 1	Triloki	Chamba Landrace	CD ($p \leq 0.05$)
Bulk density (g/ml)	0.80±0.01	0.86±0.01	0.81±0.00	0.76±0.00	0.76±0.00	0.79±0.02	0.02
True density (g/ml)	1.02±0.00	1.12±0.00	1.04±0.00	1.01±0.00	1.00±0.00	1.02±0	0.01
Porosity (g/ml)	22.22±1.27	32.54±0.64	21.61±0.89	24.67±0.56	24.19±0.70	22.83±1.79	1.63
Angle of repose (degree)	23.78±0.11	22.78±0.11	22.95±0.09	18.52±0.10	15.87±0.35	16.45±0.07	0.60
Water absorption(g/ml)	4.23±0.08	3.7±0.05	3.2±0.05	3.7±0.05	3.4±0.05	2.86±0.03	0.17
Oil absorption (g/ml)	2.76±0.12	2.43±0.18	2.6±0.15	2.93±0.08	2.73±0.08	1.06±0.03	0.20
Emulsion stability (%)	64.86±0.23	63.36±0.48	63.33±0.48	63.25±0.02	65.56±0.14	63.27±0.02	0.75

Porosity

The porosity of Kidney bean varieties viz. *Kanchan, Jwala, Baspa, Him1, Triloki* and *Chamba Landrace* were 22.22, 32.54, 21.61, 24.67, 24.19 and 22.83 g/ml respectively (Table 1). Higher porosity was found in Jwala variety (32.54 g/ml) whereas, lowest was found in Triloki variety (24.19 g/ml). Wani *et al.* (2015) evaluated porosity ranged from 33.6 to 37.5 per cent among the kidney bean cultivars. Lowest porosity was reported for Local Red cultivar. Higher the bulk density and true density, higher the porosity which is higher in Jwala variety.

Angle of repose

The angle of repose of Kidney bean varieties viz. *Kanchan, Jwala, Baspa, Him1, Triloki* and *Chamba Landrace* were 23.78, 22.78, 22.95, 18.52, 15.87 and 16.45 degree, respectively and results are presented in Table 1. Higher angle of repose was found in Kanchan variety (23.78 degree) whereas, lowest was found in Triloki variety (15.87 degree). Wani *et al.* (2015) evaluated the angle of repose which showed significant differences among the kidney bean cultivars and varied from 15.20 degree to 18.67 degree.

Water absorption

Table 1 depicted that the water absorption of Kidney bean varieties viz. *Kanchan, Jwala, Baspa, Him1, Triloki* and *Chamba Landrace* were 4.23, 3.70, 3.20, 3.70, 3.40 and 2.86 g/ml, respectively. Higher water absorption was found in Kanchan variety (4.23 g/ml) whereas, lowest was found in Chamba Landrace variety (2.86 g/ml). Siddiq *et al*. (2010) evaluated the water absorption capacity of bean flours which varied from 2.23 g/g (black) to 2.65 g/g (small red kidney). Abbey and Ibeh (1988) reported the water absorption capacity of the raw cowpea flour as 2.4 g/g flour. Water absorption capacity is important for certain product characteristics, such as the moistness of the product, starch retrogradation, and the subsequent product staling.

Oil absorption

The oil absorption of Kidney bean varieties viz. *Kanchan, Jwala, Baspa, Him1, Triloki* and *Chamba Landrace* were 2.76, 2.43, 2.60, 2.93, 2.73 and 1.06 g/ml respectively, (Table 1). Higher oil absorption was found in Him1 variety (2.93 g/ml) whereas, lowest was found in Chamba Landrace variety (1.06 g/ml). Abbey and Ibeh (1988) reported the oil absorption capacities of the raw cowpea flour that was 2.9 g/g flour. The oil absorption capacity is important for the development of new food products as well as their storage stability (particularly for flavor binding and in the development of oxidative rancidity).

Emulsion stability

The emulsion stability of Kidney bean varieties viz. *Kanchan, Jwala, Baspa, Him1, Triloki* and *Chamba Landrace* were 64.86, 63.36, 63.33, 63.25, 65.56 and 63.27 per cent, respectively (Table 1). Higher emulsion stability was found in Triloki variety (65.56 per cent) whereas, lowest was found in Him1 variety (63.25 per cent). Siddiq *et al.* (2010) evaluated the emulsion properties of different bean flours that were 45.6 to 60.5 ml/100ml. Flour with good emulsion capacities will be useful in the preparation of comminuted meat products and analogs.

Cooking properties

Swelling capacity and swelling index also displayed significant differences among the varieties. These values varied from 0.20 to 0.35 ml/seed and 0.73–0.85, respectively (Table 2). Swelling capacity and swelling index of kidney bean cultivars in the range of 0.30–0.56 mL/seed and 0.91–1.39, respectively have been reported (Saha *et al.,* 2009). Seed size, density and weight of the grain had great impact on swelling capacity and swelling index which were determined by the time taken by water to penetrate the inner core of grains and thus ultimately determined the cooking time.

The hydration capacity of flour often defines its quality and its aptitude to form viscoelastic dough. Hydration capacity and hydration index varied significantly among the varieties and were observed in the range of 0.21–0.46 g/seed and 0.34–0.75, respectively (Table 2). Hydration capacity and hydration index of bean cultivars varied between 0.31–0.59 g/seed and 0.78–1.25, respectively (Saha *et al*. 2009). Hydration capacity determines the extent to which seeds absorb water on soaking. It depends upon chemical composition of seed coat and cotyledons (Bewley *et al*. 2006). Hydration capacity and hydration index both depend on difference in seed size, seed coat thickness and water absorption characteristics of seeds therefore differences in both hydration capacity and hydration index may be attributed to differences in seed weight and seed size of KB lines.

Cooking time of kidney bean varieties varied significantly from 25 to 35 min of grain which were not soaked (Fig 1). The lowest cooking time was found in Him 1 variety (25 min) and the highest in Chamba Landrace (35 min). Cooking time of kidney bean seeds/grains after soaking for 24 hr varied between 15 to 20 min. This shows that soaking prior to cooking causes significant decrease in cooking time of kidney beans. Similar trend of decrease in cooking time was observed in kidney beans by Berrios *et al.* (1999). Breakdown of the middle lamella, leading to the easy separation of cells, had been reported to contribute to the softening of pulses during cooking (Sefa-Dedeh and Stanley 1978).

Fig 1. Cooking quality of Kidney bean varieties of Himachal Pradesh

Parameters	Varieties						
	Kanchan	Jwala	Baspa	Him 1	Triloki	Chamba Landrace	CD (p=0.05)
Elongation ratio	1.40±0.01	1.6±0.02	1.45±0.00	1.25±0.02	1.28±0.01	0.97±0.01	0.06
Length-width ratio (cooked)	1.33±0.33	0.90±0.30	1.33±0.33	1.33±0.33	1.00±0.00	1.33±0.33	N/A
Water uptake ratio	2.93±0.02	2.66±0.00	2.52±0.01	2.85±0.01	2.36±0.07	2.95±0.01	0.10
Gruel solid loss (%)	14.64±0.02	13.55±0.02	15.64±0.00	14.64±0.02	13.73±0.01	16.22±0.01	0.07
Swelling capacity (ml/seeds)	0.31±0.00	0.33±0.10	0.22±0.01	0.30±0.00	0.35±0.00	0.20±0.00	0.02
Swelling index	0.84±0.01	0.85±0.10	0.78±0.01	0.79±0.02	0.80±0.02	0.73±0.01	0.21
Hydration capacity (g/seeds)	0.23±0.03	0.21±0.01	0.33±0.03	0.26±0.03	0.46±0.03	0.43±0.03	0.05
Hydration index	0.46±0.06	0.34±0.01	0.53±0.08	0.62±0.02	0.72±0.02	0.75±0.25	0.38

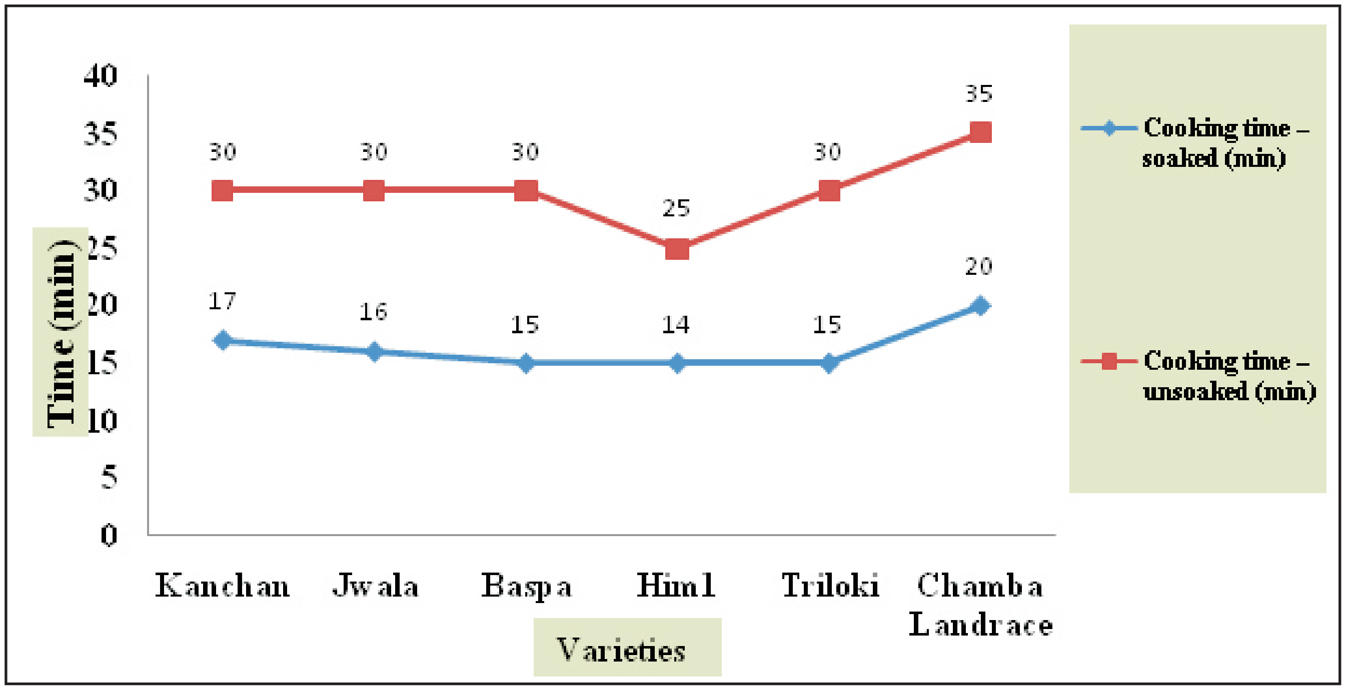

Plate 1: Cooking time of Kidney bean varieties of Himachal Pradesh

Many authors had shown that the cells of beans during cooking show separation at the optimum cooking time. Williams *et al*. (1987) reported that the cooking time is a heritable characteristic for pulses.

Solid gruel loss varied significantly among the kidney beans cultivars and varied between from 13.59 to 16.22 per cent (Table 2). Solid loss of 5.28 to 14.98 per cent has been reported for different bean cultivars (Saha *et al*. 2009) and 7.2–14 per cent for cowpea cultivars (Yeung *et al*. 2009).

Cooked length breadth ratio showed significant differences among the varieties of kidney beans and were in the range of 0.8- 1.51 (Table 2). Water uptake ratio varied significantly among the varieties of kidney beans in the range of 2.36–2.95 (Table 2). Wani *et al*. (2015) showed that cooked length breadth ratio showed significant differences among the cultivars and were in the range of 1.57–2.13. Water uptake ratio varied significantly among the cultivars in the range of 2.15–2.45.

Conclusion

From the present study, it can be concluded that the kidney bean varieties varied with respect to functional and cooking characteristics. The bulk density was varied from 0.76 g/ml to 0.81 g/ml. Water absorption and oil absorption was highest in Kanchan (4.23 g/ml) and Him 1 (2.93 g/ml), respectively. Kidney beans grown in different agro-climatic zones have difference in their physical characteristics. Hydration capacity as well as swelling capacity of the seeds/ grains of different varieties varied significantly in the range of 0.21–0.46 g/seed and 0.22–0.35 ml/seed, respectively. Cooking time of unsoaked seeds/grains of different varieties of kidney beans significantly varied and ranged between 25 to 35 min. whereas, the soaking of grains of kidney beans before cooking reduced the cooking time about 30 per cent. Triloki variety had the highest emulsion stability. Kanchan variety had the higher water absorption than other varieties of kidney bean. This information can attract consumers and processors for value-based food products by using these legume seeds.

Conflict of interest: There is no conflict of interest among the authors.

References

Abbey BW and Ibeh GO. 1988. Functional properties of raw and heat processed cowpea (*Vigna unguiculata*, L. Walp) flour. Journal of Food Science **53**: 1775-1791.

Adebowale YA, Adeyemi A and Oshodi A. 2005. Variability in the physicochemical, nutritional and antinutritional attributes of six *Mucuna* species. Food Chemistry **89**: 37-48.

Barampama S and Simard RE. 1995. Effect of soaking, cooking and fermentation on composition, *in vitro* starch digestibility and nutritive value of common beans. Plant Foods for Human Nutrition **40**: 349-365.

Berrios JDJ, Swanson BG and Cheong WA. 1999. Physicochemical characterization of stored black beans (*Phaseolus vulgaris* L.). Food Research International **32**: 669-676.

Bewley JD, Black M and Halme P. 2006. The Encyclopedia of Seeds: Science, Technology and Uses. CABI, Wallingford, UK, pp 81.

Bishnoi S and Khetarpaul N. 1993. Variability in physico-chemical properties and nutrient composition of different pea cultivars. Food Chemistry **47**: 371-373.

DES, Ministry of Agriculture & FW (DAC&FW), GoI, Success report. 2018-2019. Pulses revolution from food to nutritional security, pp 1.

Fernandes AC, Nishida W and Da Costa Proenca RP. 2010. Influence of soaking on the nutritional quality of common beans (*Phaseolus vulgaris* L.) cooked with or without the soaking water: a review. International Journal of Food Science Technology **45**: 2209-2218.

Gubbels GH and Ali-Khan ST. 1991. Effect of seed quality on cooking quality and yield of a subsequent crop of field pea. Canadian Journal of Plant Science **71**: 857-859.

Gujral HS, Sharma P and Sharma R. 2013. Antioxidant properties of sand roasted and steam cooked bengal gram (*Cicer arietinum*). Food Science Biotechnology **22**: 183-188.

Hamid S, Muzaffar S, Wani IA, Masoodi FA and Bhat MM. 2014. Physical and cooking characteristics of two cowpea cultivars grown in temperate Indian climate. Journal of the Saudi Society of Agricultural Sciences **4**(2) DOI: 10.1016/j.jssas.2014.08.002.

Hudson BJF. 1994. New and Developing source of food proteins. Chapman & Hall. London.

Klamczynska B, Czuchajowska Z and Baik B. 2001. Composition, soaking, cooking properties and thermal characteristics of starch of chickpeas, wrinkled peas and smooth peas. International Journal of Food Science and Technology **36**: 563-572.

Narain M, Siripurapu SCB, Jha H and Dwivedi VK. 1978. Physico-thermal properties of rice bran. Journal of Food Science and Technology **15**:18-19.

Mkanda AV, Minnaar A and Kock H. 2007. Relating consumer preferences to sensory and physicochemical properties of dry beans (*Phaseolus vulgaris*). Journal of the Science of Food and Agriculture **87**: 2868-2879.

Mohsenin NN. 1970. Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York, USA.

Mohsenin NN. 1980. Physical Properties of Plant and Animal Materials, second ed. Gordon and Breach Science Publishers, New York, USA.

Nimkar PM and Chattopadhyay PK. 2001. Some physical properties of green gram. Journal of Agricultural Engineering Research **80**: 183-189.

Saha S, Singh G, Mahajan V and Gupta HS. 2009. Variability of nutritional and cooking quality in bean (*Phaseolus vulgaris* L.) as a function of genotype. Plant Foods & Human Nutrition **64**: 174-180.

Satya S, Kaushik G and Naik SN. 2010. Processing of food legumes: a boon to human nutrition. Mediterranean Journal of Nutrition & Metabolism **3**: 183–195.

Sefa-Dedeh S and Stanley DW. 1978. The relationship of microstructure of cowpeas to water absorption and dehulling properties cowpeas (*Vigna unguiculata*). Journal Food Science **44**: 790-796.

Siddiq M, Ravi R, Harte JB and Dolan KD. 2010. Physical and functional characteristics of selected dry bean (*Phaseolus vulgaris* L.) flours. LWT – Food Science and Technology **43**(2): 232-237.

Vindiola OL, Seib PA and Hoseney RC. 1986. Accelerated development of the hard-to-cook state in beans. Cereal Foods World **31**: 538-552.

Wani IA, Sogi DS and Gill BS. 2013. Physical and cooking characteristics of black gram (*Phaseolus mungoo* L.) cultivars grown in India. International Journal of Food Science & Technology **48**: 2557-2563.

Wani IA, Sogi DS, Wani AA and Gill BS. 2015. Physical and cooking characteristics of some Indian kidney bean (*Phaseolus vulgaris* L.) cultivars. Journal of Saudi Society of Agricultural Sciences. doi: http://dx.doi.org /10.1016/j.jssas.2014.12.002.

Williams PC, Nakoul H and Singh KB. 1987. Relationship between cooking time and physical characteristics in chickpea. Journal of the Science of Food and Agriculture **34**: 492-497.

Yasumatsu K, Sawada K, Maritaka S, Mikasi M, Toda J, Wada T and Ishi K. 1972. Whipping and emulsifying properties of soybean products. Agricultural and Biological Chemistry **36**: 719-727.

Yeung H, Ehlers JD, Waniska RD, Alviola JN and Rooney LW. 2009. Rapid screening methods to evaluate cowpea cooking characteristics. Field Crops Research **112**: 245-252.