Instant multigrain porridge: effect of cooking treatment on physicochemical and functional properties

Harshad M. Mandge · Savita Sharma ·
Basharat Nabi Dar

Revised: 1 July 2011 / Accepted: 5 July 2011 / Published online: 2 August 2011
© Association of Food Scientists & Technologists (India) 2011

Abstract Multigrain blends of wheat, mungbean, sorghum, barley, corn (50:20:15:10:5) and flaxseeds @ 1% were processed by instantization (cooking) treatments to produce instant multigrain porridge. Cooking treatment involved three processing steps, Soaking (A: Soaked for 5 h at 50 °C, B: Soaked for 3.5 h at 65 °C), Steaming at 15 psi for 10, 15, 20 min. and drying at 40 °C. Quality evaluation (physical, textural and sensory) of multigrain porridge was used as criteria to select the best processing condition for instantization. Per cent water absorption of grains increased significantly with increase in soaking time/temperature. Complete gelatinization of starch with no stickiness in cooked grains was obtained at 65 °C/3.5 h (soaking) followed by steaming (15 psi/15 min). The results suggest that multigrain blends can be instantized into an acceptable and nutritional, traditional breakfast food (porridge). The multigrain porridge given soaking treatment at 65 °C/3.5 h and steaming treatment for 20 min was having better physical and sensory properties.

Keywords Multigrain porridge · Soaking · Cooking · Bulk density · Pasting properties

In recent years, a wide range of processed foods in ready-to-eat form have been marketed with increased

interests in health foods. Consumers also now believe in health benefits or nutrition as being desirable food qualities. Breakfast cereals have potential to contribute as nutritious food because of dietary fibre and other health significant bioactive compounds in whole grains. In addition to whole grain benefits, multigrain concept can provide breakfast foods with number of benefits associated with these grains. This multigrain blends helps to mix different whole grains to maximize their nutritional, functional and sensory properties. Apart from health significance, convenience is also a recent trend in international as well as Indian food market. Convenience products are quick and easy to prepare, thus, saves cooking time and requires few cooking skills.

In India, wide range of traditional foods are consumed as breakfast. To attract consumers, traditional products must be reformulated to meet demands for fast preparation time, convenience and health significance. Wheat porridge (*dalia*) is a major breakfast cereal in north India and it is made from cracked wheat by cooking in milk or water, and is eaten with salt or sugar added. This product offer unique advantage to incorporate multigrain concept in ready-to-eat, wholesome breakfast food.

The cooking of grains with steam under pressure is the initial process for porridge making. This process is important as it develops the grain properties necessary for the development of product characteristics such as flavour, colour and texture- primarily by gelatinisation of starchy grain fractions (Caldwell et al. 2000). The present study was carried out to investigate technological challenges associated with preparation of instant multigrain porridge, having greater nutritional value and to assess physical characteristics and cooking, sensory quality of the multigrain porridge.

H. M. Mandge · S. Sharma (✉) · B. N. Dar
Department of Food Science and Technology,
Punjab Agricultural University,
Ludhiana, Punjab 141 004, India
e-mail: savitasharmans@yahoo.com

H. M. Mandge
e-mail: harshad.mandge@yahoo.co.in

B. N. Dar
e-mail: darnabi@gmail.com

Materials and methods

Raw grains (wheat, mungbean, sorghum, barley, corn and flaxseed) were purchased from local market. The samples were thoroughly cleaned and stored in plastic bins for subsequent investigation.

Grains were analyzed for 1,000-kernel weight, bulk density and chemical components (protein, fat, ash, moisture, crude fibre) were determined using AACC (2000) methods.

Bulk density Bulk density was evaluated by measuring the weight of known volume of sample. Samples were poured into a graduated cylinder, gently tapped ten times and filled to 500 ml. Results were expressed as g/ml.

Thousand kernel weight One thousand undamaged raw grains were weighed on a weighing balance. Results are expressed as grams.

Water absorption properties of grains Water absorption properties were measured as per the procedure given by Hsu et al. (1983). Beakers containing 10 g of grains and 200 ml distilled water were placed in hot air oven at 50 °C and 65 °C. Beakers were removed from oven at every half hour intervals. Kernel surfaces were blotted dry and fractional weight increases were measured as relationship between final and initial sample weights.

Instantization treatment Grains (Wheat, sorghum, barley, corn, mungbean) were given pre-treatments for instantization.

Presoaking Soaking of different grains were done at different temperature for different time period as given below:

- A: Soaked 5 h at 50 °C
- B: Soaked 3.5 h at 65 °C

Steaming/pressure cooking Steaming/pressure cooking of soaked grains were done in autoclave at 15 psi for different time period i.e. 10, 15, 20 min.

Drying Steamed/pressure cooked grains were subjected to hot air drying in cabinet dryer at 40 °C till desired moisture content (~8%).

Milling Grains instantized by cooking treatment were coarse grinded in Lab scale Super Mill (Perten company) and sieved through ISI Mesh No.20 (0.833 mm) for medium fractions.

Blending Coarse grinded grains Wheat: Mungbean:Sorghum: Barley: Corn were blended in ratio of 50:20:15:10:5. 1% flaxseed was added to this blend formulation.

Water absorption index (WAI) Water absorption index of the product was determined by method outlined by Anderson et al. (1969). 2.5 g of ground sample was suspended in 30 ml of distilled water at 30 °C in a 50 ml tared centrifuge tube. The contents were stirred intermittently over 30 min period and centrifuged at $3,000 \times g$ for 10 min. The supernatant liquid was poured carefully into tared evaporating dish. The remaining gel was weighed and WAI was calculated as the grams of gel obtained per gram of solid.

Water solubility index (WSI) WSI was determined from the amount of dried solids recovered by evaporating the supernatant from the water absorption index test described above (Anderson et al. 1969). It was expressed as a percentage of solid in the sample extract.

Colour Colour analysis of grains and multigrain porridge was done by using Hunter Lab colorimeter (MiniScan XE Plus). The instrument was calibrated with the user supplied black plate calibration standard that was used for zero setting. Minolta supplied white calibration plates was used for white calibration setting. The sample was uniformly packed in clean petri plates with lid. The instruments were placed on the plate and three exposures at different places were conducted. The different reflectance value and colour parameters were recorded in form of tables.

Pasting characteristics

A Rapid visco analyzer (RVA) model starch Master (Newport Scientific, Warriewood, Australia) was used to determine the pasting properties of raw grains and multigrain porridge. Noted the pasting temp., peak viscosity, time to peak, breakdown, minimum viscosity, setback and final viscosity from the instrument.

In the RVA, the short temperature profile was used, a mixture of 3.5 g flour and 25.0 ml water was held at 50 °C for 1 min and subsequently heated to 95 °C at 12.2 °C/min. Holding time at 95 °C was 2.5 min. Subsequently, the sample was cooled to 50 °C at 12.2 °C/min, where it was kept for 2.1 min. The RVA parameters measured were peak viscosity (the maximum hot paste viscosity), holding strength (the trough at the minimum hot paste viscosity), and final viscosity (the viscosity at the end of the test after cooling to 50 °C and holding at this temperature). Breakdown (peak viscosity minus holding strength) and setback (final viscosity minus holding strength) were calculated from these values.

Texture analysis The texture analysis (backward extrusion) was done with TAXi-32 Texture Analyzer.

Sensory evaluation

Cooked multigrain porridge was served hot and evaluated for sensory attributes (appearance, colour, texture, stickiness, flavor and taste) through a panel of semi-trained judges using 9-point hedonic scale (Larmond 1970).

Statistical analysis of data

Proximate composition was expressed at 14% moisture. Values were mean of three replicate. Data collected from the aforesaid experiments was subjected to statistical analysis with the help of factorial completely randomized design. The least significant difference (LSD) was used as the test for significance (Singh et al. 1998).

Result and discussion

Physico-chemical properties of raw materials

Grains differed significantly with respect to physical properties i.e. 1,000 kernel weight and bulk density. Flaxseed (1.45 g/ml) and corn (1.41 g/ml) showed higher bulk density. Mungbean was observed to have lowest bulk density (1.26 g/ml). Among various grains, mungbean had highest amount of crude protein (23.7%) followed by flaxseed (19.3%). Statistically significant variability was observed in different grains with respect to ash content. Per cent fat content of all the grains ranged from 1.17 to 35.5%. Significant variation was observed in crude fiber content of grains. A glance of per cent carbohydrate values from Table 1 has depicted

that the carbohydrate content of all the used raw materials varied significantly from each other.

Physico-chemical properties of multigrain porridge

The proximate composition of multigrain porridge is depicted in Table 2. A glance at proximate composition of multigrain porridge reveals that it contains 12.80% crude protein, 1.78% fat, 1.50% crude fibre, 1.91% ash and 64.24% carbohydrate.

Physical parameter like bulk density of multigrain porridge showed significant increase over raw multigrain porridge upon cooking. Bulk density increased from 1.30 (Raw) to 1.47 (Cooked). Table 2 depicts colour values (L, a*, b*) of grains as influenced by cooking treatment. The mean L-value (lightness) for raw multigrain porridge was 53.6 and after cooking treatment the mean L-value decreased to 41.6. Since, L-value is a measure of the colour on the light–dark axis, this lowered L-value indicated the grains were losing brightness on cooking treatment. The darkness observed might be due to browning reaction as occurred during drying stage of the treatment. Mean a* value of porridge increased from 5.0 to 5.8 on cooking treatment. Mean b* value decreased from 18.4 to 15.8 on cooking treatment.

Effect of soaking on per cent water absorption of grains

Soaking behavior of grains at different time and temperature is presented in Figs. 1 (a) and (b). The curves exhibit the characteristic moisture sorption behavior whereby an initial high rate of water absorption was followed by slower absorption in later stages.

The high initial water uptake was probably due to filling of capillaries on surface of seed coats. Jones et al. (2000) observed that highly porous nature of the pericarp and its quick capillary inhibition rate was primarily responsible for a very rapid initial moisture absorption. As water absorp-

Table 1 Physico-chemical properties (expressed at 14% moisture basis) of raw materials

Type of grain	1,000 kernel weight (g)	Bulk density (g/ml)	Crude protein (%)	Ash (%)	Fat (%)	Crude fiber (%)	Carbohydrate (%)
Wheat	41.9	1.28	11.9	1.58	1.46	1.18	69.8
Sorghum	28.1	1.37	10.4	1.82	1.84	1.56	70.4
Barley	39.5	1.33	11.2	1.22	1.17	3.83	68.6
Corn	254.1	1.41	11.4	1.42	3.70	1.90	67.5
Mungbean	40.10	1.26	23.7	4.13	1.51	1.15	55.5
Flaxseed	6.00	1.45	19.3	4.96	35.5	4.43	21.8
LSD ($p \leq 0.05$)	1.75	0.05	0.50	0.08	0.39	0.14	2.15

All values are mean of three replications

Table 2 Physico-chemical properties (expressed at 14% moisture basis) of multigrain porridge

Chemical Properties				
Crude Protein (%)	Fat (%)	Crude fibre(%)	Ash (%)	Carbohydrate (%)
12.80	1.78	1.50	1.91	64.24
Physical Properties				
Color	Bulk density (g/ml)			
	L	a	b	
Raw	53.6	5.0	18.4	1.30
Cooked	41.6	5.8	15.8	1.47

All values are mean of three replications

tion proceeded the soaking rate started to decline due to the effect of increased extraction rate of soluble materials and the filling of free capillary and intercellular spaces with water (Phlak et al. 1989).

The water absorption curves indicate that the amount of water absorbed by grains during soaking was also a function of soaking temperature. Grains soaked at high temperature (65 °C) for variable time exhibited more water absorption than that soaked at lower temperature (50 °C). This increase was due to changes in diffusion resistance of grains. Also grains were found to expand and soften at higher temperature.

Fig. 1 **a** Effect of soaking at 50 °C/5 h on per cent water absorption of grains.* Values are mean of 3 replications. **b** Effect of soaking at 65 °C/3.5 h on per cent water absorption of grains. * Values are mean of 3 replications

Wheat grains showed 50.85% of water absorption at 65 °C in 3.5 h while at 50 °C it took 5 h to attain 47.80% water absorption. Corn, mungbean, sorghum and barley behaved similarly with respect to water absorption at varied temperature and time conditions. Thus, the application of higher temperature had found potential to shorten the soaking time necessary to reach a given moisture contents for further stage of cooking. Kishaninejad et al. (2008) observed that per cent water absorption of cereal grains increased when soaking temperature increased from 25 °C to 65 °C and the soaking time decreased with increase in soaking temperature. Similar results have been reported for soybean, peanut, pigeon pea, rice, cowpea, wheat and corn (Singh and Kulshrestha 1987; Engels et al. 1987; Hendrick et al. 1987; Sopade and Obekpa 1990). Mungbean showed highest rate of water absorption with time followed by barley. Wheat, corn and sorghum had shown lower rate of water absorption. This might be due to difference in physical structure (pericarp layer) and chemical components (carbohydrate and protein) among these grains.

Water absorption was also associated with the pronounced swelling of grains and a small but definite leaching of solids. Barley and mungbean showed more leaching of solids in soaked water. Mungbean seed demonstrated higher degree of swelling with soaking as compared to other grains.

Physical characters and sensory evaluation of multigrain porridge

WAI can be used a gelatinisation index. It indicates the ability of flour to absorb water, and depends on availability of hydrophilic groups which binds water molecules and on gel forming capacity of macromolecules. The processing conditions (soaking and steaming) affected WAI of multigrain porridge. Mean WAI of 3.45 g/g was obtained for instant multigrain porridge presoaked at 50 °C/5 h and steamed for different time. Soaking temperature had positive effect on WAI of grains as inferred from higher mean WAI for soaking condition of 65 °C/3.5 h (4.15 g/g). WAI was also found to increase with increasing steaming time. The value of WAI was higher at 20 min of steaming time under different soaking conditions (3.81 g/g and 4.28 g/g), thus, indicating higher degree of gelatinisation with increased steaming time. The higher water absorption phenomenon of

instant multigrain porridge could be associated with denaturation of proteins at higher temperature during processing.

WSI is used as a measure for starch degradation. Increased steaming time resulted in increased water solubility indices of instant multigrain porridges. The higher WSI indicated more degradation of starch under the steaming conditions which leads to more number of soluble molecules. Mean WSI of 21.14% was observed for instant multigrain porridge presoaked at 50 °C/5 h and steamed for different time; which was higher than that for mean WSI for soaking treatment at 65 °C/3.5 h (19.75%). Instant multigrain porridge prepared by soaking pre-treatment at 50 °C/5 h and steaming for 20 min observed to have highest WSI (23.20%).

Sensory attributes (appearance, mouthfeel, flavour and overall acceptability) of instant multigrain porridge, instantized by cooking treatment, were presented in Table 3. Appearance, mouthfeel and flavor changed non-significantly under different processing conditions. The sensory parameter of mouthfeel was more correlated with degree of cooking of instant multigrain porridge, thus influencing overall acceptability score for multigrain porridge treated under different processing conditions. Mean overall acceptability of multigrain porridge prepared by soaking at 65 °C/3.5 h was higher (8.02) than that of samples given soaking treatment at 50 °C/5 h (7.78). The overall acceptability score of multigrain porridge was highest at 65 °C/3.5 h soaking and 20 min steaming treatment (8.27). Multigrain porridge which is more fully cooked with higher steaming time, had more acceptable mouthfeel. The highest mouthfeel score was given for 20 min steamed multigrain porridge. The lower score for overall acceptability of multigrain porridge steamed for lesser time, was associated

with decreased flavour score, particularly floury flavour of undercooked multigrain porridge.

Pasting properties of multigrain porridge

Cooking treatment of grains resulted in the change of RVA profile. It can be seen from the RVA profile that pasting properties of multigrain porridge was influenced by cooking treatment (Table 4). Mean value of peak viscosity for multigrain porridge presoaked at 50 °C/5 h and then steamed for different time was, found to be 65 °Cp. Mean peak viscosity value further decreased to 555.6 cp at higher soaking temperature (65 °C). Thus, soaking temperature was found to be negatively correlated with peak viscosity and positively correlated with starch degree of gelatinization. With increase in steaming time, values for peak viscosity become progressively lower. Grains soaked at 50 °C/5 h and steamed for 10 min had given highest peak viscosity value of 695 cp.

The peak viscosity value further reduced to 62 °Cp at 20 min steaming under same soaking conditions. The lower values of peak viscosity after steaming might be due to starch properties. Starch in cooked grains was already saturated with water during steaming of grains. Therefore, on rehydration it absorbed less water and did not reach to that peak viscosity which was given by raw multigrain blend.

Mean hold viscosity, final viscosity values for multigrain porridge were 469.3 cp and 56 °Cp, respectively, under soaking conditions of 50 °C/5 h. Control sample had hold viscosity of 778 cp, while this value at 20 min steaming reduced to 333 cp and 393 cp under different soaking conditions. The lowest hold

Table 3 Physical characters and sensory evaluation of multigrain porridge

Processing conditions		Physical properties		Sensory score			
Soaking temp(°C)/time (hrs)	Steaming time (min)	WAI (g/g)	WSI (%)	Appearance	Mouth feel	Flavor	Overall acceptability
Control		1.27	11.3	7.99	7.19	7.10	7.42
50°C/5 h	10	3.05	19.3	7.96	7.83	7.67	7.28
	15	3.50	20.9	8.03	7.99	7.79	7.93
	20	3.81	23.2	8.23	8.19	8.0	8.14
Mean		3.45	21.1	8.07	8.0	7.82	7.78
65°C/3.5 h	10	4.11	19.5	7.94	7.87	7.76	7.85
	15	4.07	19.5	8.02	7.91	7.89	7.94
	20	4.28	20.2	8.47	8.01	8.01	8.27
Mean		4.15	19.7	8.14	7.93	7.88	8.02
LSD ($p \leq 0.05$)			0.65	NS	NS	NS	0.08

*expressed at 14% moisture basis

All values are mean of three replications

Table 4 Pasting properties of multigrain porridge

Processing conditions		Pasting temperature (°C)	Peak viscosity (cp)	Hold viscosity (cp)	Final viscosity (cp)	Break down (cp)	Set back (cp)
Soaking temp(°C)/ time (hrs)	Steaming time (min)						
Control		90.3	995	778	815	217	37
50 °C/5 h	10	91.5	695	617	656	78	39
	15	92.6	635	398	512	237	114
	20	92.8	620	393	512	227	119
Mean		92.3	650	469.3	560	180.7	90.7
65 °C/3.5 h	10	92.5	648	403	578	245	175
	15	93.1	592	421	596	171	175
	20	91.2	427	333	459	94	126
Mean		92.2	555.6	452.3	544.3	170	158.7
LSD ($p \leq 0.05$)		0.95	9.17	8.88	9.35	4.23	6.32

*expressed at 14% moisture basis

All values are mean of three replications

viscosity values were recorded at 20 min steaming treatment of multigrain porridge. Reason behind lower hold viscosity of instant multigrain porridge might be attributed to the higher proportion of soluble starch in instantized multigrain porridge than the raw multigrain porridge.

Final viscosity values were found to be decreased with increased steaming time and soaking temperature. Final viscosity values indicate ability of grains to form a viscous paste/gel after cooking and cooling. Therefore, steamed grains found to have less ability to form a gel. Srieko et al. (2005) found that there was considerable decrease in values of peak viscosity, hold viscosity and final viscosity, after thermal treatment. This is because of complete gelatinization of all the starches. Thermally treated grains also showed absence of gelatinization peak.

The breakdown viscosity changed non- significantly after steaming. It might be due to pregelatinized starch in

steamed grains. Low setback values observed during cooling in RVA profile. These values were in conformity with work done by Srieko et al. (2005).

Textural properties of multigrain porridge

Backward extrusion of multigrain porridge was done with probe diameters 40 mm and different piston speeds (Table 5).

The resultant multigrain porridge was found to be more consistent, less firm and more cohesive with higher degree of instantization treatment. For the multigrain porridge soaked at 50 °C and steamed for 10, 15 and 20 min, the value of consistency was found to be 1912.44, 3004.64 and 2803.33 g.sec, respectively. The value of consistency increased with increased soaking temperature. It may be because of higher amount of gelatinization at higher temperature which resulted in improved consistency of

Table 5 Textural properties of multigrain porridge

Processing conditions		Consistency g.sec	Firmness G	Cohesiveness g.sec	Index of viscosity G
Soaking temp (°C)/time (hrs)	Steaming time (min)				
Control		2379.5	346.7	−1445.5	−101.4
50 °C/5 h	10	1912.4	257.8	−1565.4	−103.5
	15	3004.6	201.9	−1830.3	−121.2
	20	2803.3	187.5	−643.2	−83.7
Mean		2573.5	215.7	−1364.3	−102.8
65 °C/3.5 h	10	1952.5	261.9	−2155.4	−143.7
	15	3270.3	219.6	−2046.5	−135.2
	20	3549.5	236.9	−1232.7	−162.1
Mean		2924.1	239.4	−181.5	−147.0
LSD ($p \leq 0.05$)		21.09	11.23	22.79	10.83

*expressed at 14% moisture basis

All values are mean of three replications

multigrain porridge. The mean value of consistency for multigrain porridge processed at soaking condition of 50 °C/5 h was recorded as 2573.47 g.sec, while the consistency increased to 2924.12 g.sec at higher soaking temperature (65 °C). Multigrain porridge instantized at lower temperature and steamed for less time become more firm and less cohesive.

Conclusion

A characteristic water absorption properties was observed for all grains under provided soaking conditions. Grains soaked at high temperature (65 °C) for variable time exhibited more water absorption than that soaked at lower temperature (50 °C). Wheat subjected to soaking treatment at 65 °C for 3.5 h followed by steaming for 15 min, attained excellent gelatinization; while no clumpiness and stickiness was developed in wheat under these processing conditions. Slight to high stickiness was observed in presoaked and steamed barley. More the steaming time for barley, more the clumpiness and stickiness were observed in the grains. Both corn and sorghum showed no clumping and stickiness during steaming treatment.

Each stage of cooking treatment i.e. soaking, steaming and drying had significant impact on the bulk density of grains. Soaking caused increase in bulk density of raw grains, the values of bulk density further decreased on steaming. The dried grains become denser as inferred from higher value of mean bulk density. Cooking treatments had a significant effect on L^* , a^* and b^* values of grains. After cooking treatments, lightness (L^*) value of grains decreased, redness (a^*) increased and b^* (yellowness) decreased significantly. Thus, indicating loss of brightness after cooking treatment.

Natural pasting properties of raw material was altered after instantization treatments of cooking. Instant multigrain porridge did not observed to have characteristic peak viscosity. With increase in steaming time, values for peak viscosity become progressively lower. Similarly, other RVA values (Hold viscosity, final viscosity, breakdown, set back) of multigrain porridge found to be decreased with increased steaming time and soaking temperature. The value of consistency of multigrain porridge as judged by backward extrusion probe was found to increase with increased soaking temperature and steaming time. The firmness and cohesiveness values for cooked multigrain porridge was

found to be better. The processing conditions (soaking and steaming) affected WAI and WSI of multigrain porridge. Soaking temperature had positive effect on WAI of grains as inferred from higher mean WAI for soaking temperature. WAI was also found to increase with increasing steaming time. Appearance, mouthfeel and flavor changed non-significantly under different processing conditions. The sensory parameter of mouthfeel was more correlated with degree of cooking of instant multigrain porridge, thus influencing overall acceptability score for multigrain porridge treated under different processing conditions. The multigrain porridge prepared by soaking treatment at 65 °C for 3.5 h and steaming for 20 min was found to most acceptable with respect to all sensory parameters studied.

References

- AACC (2000) Approved Methods of American Association of Cereal Chemists, 10th edn. The Association St, Paul
- Anderson RA, Conway HF, Pfeifer VF, Griffin EL (1969) Roll and extrusion cooking of grain sorghum grits. *Cereal Sci Today* 14:4–12
- Caldwell EF, Fast RB, Ievolella J, Lauhoff C, Levis H, Milles RC, Slide L, Strahm BS, Cohalen PJ (2000) Cooking of ready to eat fast food cereals. *Cereal Foods World* 45:244–52
- Engels C, Hendrick M, Tobback P (1987) Limited multiplayer desorption of brown, parboiled rice. *Int J Food Sci Technol* 22:219–23
- Hendrick M, Engels C, Tobback P (1987) Three dimensional TLM models for water diffusion in white rice. *J Food Eng* 6:187–92
- Hsu KH, Kim CJ, Wilson LA (1983) Factors affecting water uptake of soyabeans during soaking. *Cereal Chem* 60:208
- Jones D, Chennaswamy R, Tan Y, Hanna M (2000) Physicochemical properties of ready-to-eat breakfast cereals. *Cereal Foods World* 40:164–68
- Kishaninejad M, Dehghani AA, Kashiri M (2008) Modelling of wheat soaking using two artificial neural networks (MLP and RBF). *J Food Engg* 72:132–35
- Larmond E (1970) Methods for sensory evaluation of food. Canada Department of Agriculture Pubn 1284
- Phlak LC, Caldwell KB, Stanley DW (1989) Comparison of methods used to characterize water imbibition in hard-to-cook beans. *J Food sci* 54:326–29
- Singh BPN, Kulshrestha SP (1987) Kinetics of water sorption by soyabean and pigeon pea grains. *J Food Sci* 52:1538–41
- Singh S, Bansal ML, Singh TP, Kumar R (1998) Statistical methods for research workers. Kalyani, New Delhi
- Sopade PA, Obekpa JA (1990) Modelling water absorption in soyabean, cowpea and peanuts at three temperatures using Peleg's equation. *J Food Sci* 55:1084–87
- Srikeo K, Furst JE, Hsken RW, Ashton JF (2005) Physical properties of cooked wheat grains as affected by cooking temperature and duration. *Int J Food Properties* 8:469–79