Physico-Chemical properties of different millets and relationship with cooking quality of millets

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Physico-Chemical properties of different millets and relationship with cooking quality of millets

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Abstract
The aim of the present study is to determine the physico- chemical properties of different selected millets and relationship with cooking quality (*viz*., Finger Millet, Kodo Millet, Foxtail Millet, Pearl Millet, Barnyard Millet, Little Millet, Proso Millet and Sorghum). Eight varieties of millets were procured from local market of Kolar and utilized for the study. The highest thousand kernel grain weight was observed in sorghum (36.9±0.78g) and pearl millets (9.36 ± 1.20g) followed by proso millet (4.97 ± 0.15g), Foxtail Millet (4.25 ± 0.45g), Little Millet (4.19 ± 0.35g), Barnyard Millet (4.16 ± 0.23g), Kodo Millet (4.15 ± 0.31g) and Finger Millet (3.12 ± 0.12g) respectively. The hydration index was observed maximum in kodo millet (36.16 ± 1.02) followed by sorghum (35.59± 0.21) and pearl millet (23.41± 0.97). Least hydration index was indentified in proso millet (13.48 ± 0.56). The hydration capacity was highest in sorghum (12.6 ± 0.51) as compared to the other millets. The swelling index and swelling capacity was higher in sorghum (54.28 ± 0.85 and 22.8 ± 0.98) followed by pearl millet (39.09 ± 1.23 and 4.3 ± 0.24). The total carbohydrates, crude protein, total fat, crude fibre, total ash and moisture content of different millets ranged from 60-72g, 7-12g, 1.5-6g, 3-11g 1-5.5g and 10-14% respectively. Sorghum showed highest cooking time (40 minutes) followed by Pearl millet (34 minutes) and Finger millets (23 minutes). Among eight millets were good source of protein, fibre and had low in fat content. Among the selected millets finger millet, pearl millet and sorghum were 80-90% germinated.

Keywords: millets, physical, chemical, functional, hydration capacity and germination

1. Introduction

Millets are a group of small - seeded species of cereal crops belonging to the family Gramineae and grown widely around the world for food and fodder. The most important characteristics of millets are their unique ability to tolerate and survive under adverse condition of continuous or intermittent drought as compared to most other cereals like maize and sorghum. India has the largest millet producing country in the world with a total area of 23 million ha and small millets alone account for about 3.5 million hectare (Stanly and Shanmugam 2013) [12]. The major millets are pearl millet, foxtail millet, proso millet and finger millet. The most important minor millets cultivated in India are barn-yard millet, kodo millet, little millet, guinea millet and brown top millet (Yang *et al*., 2012) [15]. Millets are more nutritious and they are non-glutinous and non-acid forming and easy to digest. Millets are good sources of energy, protein, fatty acids, vitamins, minerals, dietary fibre and polyphenols. Millet proteins contain good sources of essential amino acids except lysine and threonine but have relatively high quantity of sulphur containing amino acids (methionine and cysteine). Millets are rich sources of phytochemicals, micronutrients and antioxidants, such as phenolic acids and glycated flavonoids (Singh *et al*., 2012) [11].

Millets are not placed as a single important commodity in the North American and European food basket at the present time, but their importance as an ingredient in multigrain and gluten-free cereal products has been highlighted. However, in many African and Asian areas, millets serve as a major food component and various traditional foods and beverages, such as bread (fermented or unfermented), porridges, and snack foods are made of millet, specifically among the non affluent segments in their respective societies (Chandrasekara and Shahidi 2011; Chandrasekara *et al*., 2012) [5-6]. In addition to their nutritive value, several potential health benefits such as preventing cancer and cardiovascular diseases, reducing tumor incidence, lowering blood pressure, risk of heart disease, cholesterol and rate of fat absorption, delaying gastric emptying, and supplying gastrointestinal bulk have been reported for millet (Truswell 2002, Gupta *et al*., 2012) [13, 7]. Millet grains, before consumption and for preparing of food, are usually processed by commonly used traditional processing techniques include decorticating, malting, fermentation, roasting, flaking, and grinding to improve their edible, nutritional, and sensory properties. There is a growing interest in these crops because of the technological possibilities of its utilization in industrial applications as starch production and value addition in extruded products. Therefore, consequent on the large scale production and commercial exploitation of the crop is the need to study the physical and mechanical attributes of these crops, which are important in the design of equipment for handling, cleaning, storing and processing. Hence, the present study aims to determine the Physical and Chemical Properties of Different Millets and relationship with their cooking quality.

2. Materials and Methods

Test Material: Eight varieties of millets were procured from local market of Kolar and utilized for the study. The different millets that were procured are Finger Millet, Kodo Millet, Foxtail Millet, Pearl Millet, Barnyard Millet, Little Millet, Proso Millet and Sorghum.

2.1 Physical properties of millets
Varieties of millets samples were assessed for Physical properties such as 1000 kernel weight, volume, and density were studied using standard procedures. One thousand Kernels were randomly selected from each variety and weighed. The volume of the same thousand kernels was measured using measuring cylinder. Density of the grains was calculated from thousand kernel weight by volume.

2.2 Functional Properties of Millets
Functional properties of different millets were studied include Hydration capacity, Hydration Index, Swelling capacity, Swelling Index.

2.2.1 Hydration capacity (g/ 1000 kernels) and Hydration index
The hydration capacity of thousand kernel millet grains was calculated as the difference in weight of grain after soaking for 24 hours. It was expressed as weight per gram (Williams *et al*., 1983) [14]. In this method randomly selected thousand kernel millet grains were soaked in distilled water (1:10: *w/v)* under ambient conditions. Hydration index was calculated by using the formula given by (Kantha *et al*., 1986) [9].

$$\text{Hydration index} = \frac{\text{Hydration capacity per 1000 seeds}}{\text{Original dry weight of 1000 grain}} \times 100$$

2.2.2 Swelling capacity and Swelling Index
The swelling capacity of grains was assessed by modifying the methods of (Williams *et al*., 1983) [14]. The soaked seeds were blot dried, to remove the superfluous water and transferred to a measuring cylinder containing known volume of water. The change in volume was recorded and swelling capacity was calculated. Swelling index of grains was calculated as described by (Kantha *et al*., 1986) [9] using the formula.

$$\text{Swelling index} = \frac{\text{Swelling capacity per 1000 seeds}}{\text{Seed volume per 1000 seeds}} \times 100$$

2.3 Germination
Randomly selected thousand grains were soaked for 24 hours in 200ml distilled water. Soaked grains were drained and tied in a muslin cloth and placed in a dark condition for 36 hours for germination. The sprouted grains were counted and classified as completely, partially or not germinated based on germination capacity. The values were expressed in percentage.

2.4 Chemical properties
By using the standard methods, all the samples moisture, Ash, crude fat, crude fibre, and crude protein and carbohydrate contents of each food sample were analyzed. Sample meals of each variety was weighed into a previously weighed dry moisture plate and dried in an oven at 105°C to a constant weight. Moisture content was calculated by the formula given in (AOAC, 2005) [1]. The crude protein was determined using the micro-Kjeldahl procedure (AOAC, 2005) [1]. The values of Nitrogen (N) were multiplied by 6.25 and expressed as crude protein. The Ash content was determined by combustion method igniting the samples in a muffle furnace, at 600°C, for 3-4 hours (AOAC, 2005) [1]. Moisture free flour samples of each variety were weighed in moisture free thimbles and crude fat was extracted by refluxing with petroleum ether in a soxhlet apparatus. Per cent crude fat was calculated (AOAC, 2005) [1]. Crude fibre was estimated by acid alkali digestion method. The residue obtained after digestion was transferred to a Gooch crucible prepared with a thin compact layer of ignited asbestos and dried at 105°C in an air oven and its weight was recorded. The difference in the two weights was taken as the weight of the crude fibre (AOAC, 2005) [1]. Total carbohydrates content was calculated by subtracting the sum of the values for moisture, crude protein, crude fat, crude fibre and ash from 100.

2.5 Cooking Quality of Millets
2.5.1 Cooking Time
A known quantity of millets (25g) was soaked for 30mins and were subjected to boiling temperature in predetermined constant amount of water (3.5 times) in a steel vessel and was cooked till the desired consistency of cooked grain is obtained. The time required for complete gelatinization was noted down. Cooking time was noted by pressing the cooked grains between the glass slides and the disappearance of chalky spot of millets was taken as a measure of doneness

2.5.2 Cooked weight (g) and volume (ml)
The cooked seeds (raw weight - 25gm) were drained and the superfluous water removed using an absorbent paper. The cooked weight and volume (water displacement method) was measured. The change in weight was recorded. The difference in weight and volume before and after cooking was found and increase in weight and volume of the seeds was calculated.

2.5.3 Popping
1000 grains were popped by application of oil and subjected to popping in heavy bottom pan. The popped grains were categorized as completely or partially popped and un-popped and the values were expressed in percentage.

2.6 Statistical Analysis
The statistical analysis of the results was done with ANOVA using SPSS 16.0 software (Analysis of Variance). The results were presented as means ± SD of different millets. Level of significance was set at $P \leq 0.05$.the interrelationship between Physical and chemical properties with cooking quality, germination, popping quality of millets were analyzed by Correlation coefficient.

3. Results and Discussion

Table 1: Physical Properties of Different Millets

Millets	Thousand Kernel Weight (gms)	Thousand Kernel Volume (ml)	Density (gm/ml)
Finger Millet	3.12 ± 0.12	4.34 ± 0.51	0.72 ± 0.02
Kodo Millet	4.15 ± 0.31	4.24 ± 0.75	0.97 ± 0.04
Foxtail Millet	4.25 ± 0.45	6.21 ± 0.35	0.68 ± 0.03
Pearl Millet	9.36 ± 1.20	11.63 ± 1.0	0.80 ± 0.11
Barnyard Millet	4.16 ± 0.23	4.15 ± 0.50	1.00 ± 0.004
Little Millet	4.19 ± 0.35	4.26 ± 0.28	0.98 ± 0.01
Proso Millet	4.97 ± 0.15	4.63 ± 0.35	1.07 ± 0.001
Sorghum	36.94 ± 0.78	42.69 ± 1.25	0.86 ± 0.03

The physical parameters like thousand kernel grain weight, seed volume and bulk density were represented in Table-1, The highest thousand kernel grain weight was observed in sorghum (36.9±0.78g) and pearl millets (9.36 ± 1.20g) followed by proso millet (4.97 ± 0.15g), Foxtail Millet (4.25 ± 0.45g), Little Millet (4.19 ± 0.35g), Barnyard Millet (4.16 ± 0.23g), Kodo Millet (4.15 ± 0.31g) and Finger Millet (3.12 ± 0.12g) respectively. The present study is in accordance with the study conducted by (Suman Verma *et al*., 2015) the result showed that thousand kernel grain weight highest in sorghum as compared to other millets and least was Finger Millet. (Serna-Sadivar and Rooney 1995) [10] reported that thousand kernel grain weight maximum in sorghum (30g) followed by pearl millet, proso millet, foxtail millet and finger millet with the values of 8g, 6.1g 5g, and 2.5g respectively. The maximum thousand grain volume was observed in Sorghum (42.69 ± 1.25 ml) followed by pearl millet (11.63 ± 1.0ml), foxtail millet (6.21 ± 0.35ml), proso millet (4.63±0.35ml), little millet (4.26 ± 0.28ml), finger millet (4.34 ± 0.51ml), kodo millet (4.24 ± 0.75m) and barnyard millet (4.15 ± 0.50ml). proso millet and barnyard millet had the highest bulk density followed by other millets. Grain density is useful information for transporters, marketers and percent floaters is an indirect method of determining grain density, which is also a measure of hardness (Badau *et al*., 2002) [3]. Physical characteristics of grains are determined for various reasons. Grain dimensions are very important in cleaning, specifically threshing operations. In these operations, screens are necessary, because it allows the passage of specific size of the grains and various unwanted materials (Brennan *et al*., 1981) [4].

Table 2: Functional Properties of Millets

Millets	Weight after Soaked (g)	Hydration Capacity (g/1000 kernels)	Hydration Index	Volume after soaking (ml)	Swelling Capacity (ml/1000kernels)	Swelling Index
Finger	3.45 ± 0.23	0.45 ± 0.12	15.23 ± 0.40	4.5 ± 0.43	0.5 ± 0.52	12 ± 0.89
Kodo	5.44 ± .031	1.44 ± 0.13	36.16 ± 1.02	6.44 ± 0.98	2.44 ± 0.03	61 ± 1.13
Foxtail	4.68 ± 0.23	0.68 ± 0.04	17.96 ± 0.58	6.2 ± 0.31	0.2 ± 0.04	3.33 ± 0.45
Pearl	11.07 ± 0.12	2.07 ± 0.10	23.41± 0.97	15.3 ± 1.24	4.3 ± 0.24	39.09 ± 1.23
Barnyard	4.64 ± 0.34	0.64 ± 0.63	16.62 ± 0.18	6.2 ± 0.18	2.2 ± 0.08	55 ± 0.13
Little	4.68 ± 0.42	0.68 ± 0.09	17.31 ± 0.45	6.4 ± 0.45	2.4 ± 0.54	60 ± 1.15
Proso	4.52 ± 0.57	0.52 ± 0.06	13.48 ± 0.56	4.6 ± 0.69	0.6 ± 0.17	15± 0.45
Sorghum	48.6 ± 1.25	12.6 ± 0.51	35.59± 0.21	64.8 ± 1.24	22.8 ± 0.98	54.28 ± 0.85

Table-2 showed the functional properties of the millets, The results revealed that hydration index was observed maximum in kodo millet (36.16 ± 1.02) followed by sorghum (35.59± 0.21) and pearl millet (23.41± 0.97). Least hydration index was indentified in proso millet (13.48 ± 0.56). The hydration capacity was highest in sorghum (12.6 ± 0.51) as compared to the other millets. The swelling index and swelling capacity was higher in sorghum (54.28 ± 0.85 and 22.8 ± 0.98) followed by pearl millet (39.09 ± 1.23 and 4.3 ± 0.24). The swelling power and solubility of starch granules showed a great evidence of interaction on the starch chains between the amorphous and crystalline regions. When starch was subjected to heating in excess water, there is a relaxation of the crystalline structure and the groups of amylose and amylopectin associate with water molecules through hydrogen bonding. This causes an increase in the swelling power and the solubility of the granules (Hoover, 2001) [8].

Table 3: Chemical properties of millets (gm/100gms):

	Moisture (g)	Crude Protein (g)	Total Fat (g)	Ash (g)	Total Carbohydrates (g)	Crude Fibre (g)
Finger Millet	11.84 ± 0.20	7.95 ± 0.52	1.87 ± 0.17	1.97 ± 0.11	65.19 ± 1.02	11.18 ± 1.23
Kodo Millet	14.19 ± 0.47	9.82 ± 0.43	2.65 ± 0.11	1.63 ± 0.13	65.32 ± 0.99	6.39 ± 0.35
Foxtail Millet	12.13 ± 0.61	11.75 ± 1.15	3.79 ± 0.53	3.23 ± 0.32	62.41 ± 0.97	6.7 ± 0.42
Pearl Millet	8.97 ± 0.25	11.12 ± 1.03	5.21 ± 0.65	1.13 ± 0.21	62.12 ± 1.25	11.45 ± 1.23
Barnyard Millet	12.35 ± 0.23	10.98 ± 0.77	3.32 ± 0.21	4.21 ± 0.34	55.54 ± 1.03	13.6 ± 1.24
Little Millet	11.53 ± 0.45	10.25 ± 0.65	3.92 ± 0.51	1.26 ± 0.15	65.32 ± 2.14	7.72 ± 0.59
Proso Millet	12.97 ± 0.67	11.65 ± 0.89	3.46 ± 0.18	2.97 ± 0.26	63.75 ± 0.96	5.2 ± 0.21
Sorghum	10.98 ± 0.74	9.49 ± 0.35	1.69 ± 0.14	1.42 ± 0.17	66.21 ± 0.89	10.22 ± 0.90

A chemical property of the millets presented in Table, 3, The findings indicates that there was a wide variation among the nutrient composition of each millet. In the present study was established the total carbohydrates, crude protein, total fat, crude fibre, total ash and moisture content of different millets ranged from 60-72g, 7-12g, 1.5-6g, 3-11g 1-5.5g and 10-14% respectively. These results are similar those reported by (saleh *et al*., 2013) [2] where total carbohydrates, protein, total fat, crude fibre, total ash and moisture content of millets ranges from 60-72g, 7.7-12.5g, 1.5-5.2g, 2-13.6g, 1.6-5.4, and 12% respectively. Among the millets kodo millet was highest moisture content (14.19 ± 0.47) followed by proso millet (12.97 ± 0.67), Barnyard Millet (12.35 ± 0.23), Foxtail Millet (12.13 ± 0.61) and least moisture content was in Pearl Millet (8.97 ± 0.25). The protein content was recorded highest in Foxtail Millet (11.75 ± 1.15), Proso Millet (11.65 ± 0.89), Pearl Millet (11.12 ± 1.03) and Little Millet (10.25 ± 0.65) respectively. The least protein content was observed in Kodo Millet, Sorghum and Finger Millet (7.95 ± 0.52). Present study revealed that total fat content was predominant in Pearl Millet (5.21 ± 0.65) as compared to other millets. Ash content was reported highest in Barnyard Millet (4.21 ± 0.34) followed by Foxtail Millet (3.23 ± 0.32) and Proso Millet (2.97 ± 0.26). The total carbohydrates content was highest in Sorghum (66.21 ± 0.89) and lowest in Barnyard Millet (55.54 ± 1.03). Among the selected millets the highest crude fibre content was observed in Barnyard Millet (13.6 ± 1.24) followed by Finger Millet (11.18 ± 1.23) and Sorghum (10.22 ± 0.90). The present study is in accordance with the study conducted by (saleh *et al*., 2013) [2].

Table 4: Cooking Quality of Different millets

Millets	Volume of grains (ml per 10g)	Cooking time (min)	% increase in weight
Finger	13.3	23	60
Kodo	10.5	5	230
Foxtail	10.5	12	130
Pearl	12	34	150
Barnyard	10.5	5	190
Little	11	5	260
Proso	10.5	14	90
Sorghum	12.872	40	120

The findings from the above table-4 revealed that, with respect to the cooking time Sorghum showed highest cooking time (40 minutes) followed by Pearl millet (34 minutes) and Finger millets (23 minutes). Least cooking time was observed among kodo millet, Barnyard millet and little millet (5 minutes). Percentage increase in weight after cooking was higher in little millet (260%) followed by kodo millet (230%) and Barnyard millet (190%). However, finger millet showed the least percentage increase in weight after cooking (60%).

Table 5: Germination and Popping Quality of millets

	Germinated millets (%)			Popped millets (%)		
Millets	Complete	Partial	Not germinated	Complete	Partial	Un popped
Finger	91	6	4	93	5	2
Kodo	0	0	100	0	0	100
Foxtail	0	0	100	0	0	100
Pearl	80	13	7	91	6	3
Barnyard	0	0	100	0	0	100
Little	0	0	100	0	0	100
Proso	0	0	100	0	0	100
Sorghum	81	16	3	95	4	1

Table 5, represented germination and popping quality of millets, It was observed that finger millet, pearl millet and Sorghum were germinated and the rest of the millets were not exhibit germination. Among the popped millets finger millet, pearl millet and Sorghum were found to be popped and the rest of the millets were not exhibit popping.

Table 6: Relationship between Cooking Time with Physico-Chemical Properties of Millets

Millets	Density (gm/Ml)	Hydration Capacity (g/1000 Kernels)	Hydration Index	Swelling Capacity (G/1000 Kernels)	Swelling Index	Moisture (g)	Crude Protein (g)	Total Fat (g)	Ash (g)	Total CHO (g)	Crude Fibre (g)
Finger Millet	0.61*	-0.52*	-0.49*	-0.41	-0.31	0.23	0.29*	0.16	0.12	0.35	0.39*
Kodo Millet	-0.53	-0.46	-0.42*	-0.47*	-0.43*	-0.29	0.36	0.11	0.19	0.43	0.41
Foxtail Millet	-0.43	-0.23*	-0.15*	0.27	0.36	0.49	0.53*	0.17	0.21	0.47*	0.38
Pearl Millet	0.56*	0.26*	0.19*	0.24*	0.33*	0.47	0.51*	0.12	0.17	0.45	0.35*
Barnyard Millet	0.52*	0.28	0.18	-0.43*	-0.46*	-0.42	0.54	0.16	0.23*	0.44	-0.37
Little millet	0.55	0.31	0.21	-0.35*	-0.41*	0.45	0.51	0.18	0.31	0.41	-0.31
Proso millet	-0.49	-0.36	-0.46	-0.29	-0.39	-0.37	0.49	0.23	0.26	0.39*	0.44
Sorghum	0.63*	0.27*	-0.17*	0.31*	0.45	0.33	0.45*	0.25	0.25	0.49*	0.29*

* Significant at 5% evel

Table 6, indicates the relationship between cooking times with physic-chemical properties of the millets, The results showed that cooking time of finger millet revealed that positive significant relationship with respect to density (r= +0.61*), crude protein (r= +0.29*) and crude fibre (r= + 0.39*) where as negative significant relationship with hydration capacity (r= -0.52*) and hydration index (r= - 0.49*). Further, cooking time of kodo millet shows negative significant relationship with hydration index, swelling capacity and swelling index. However, with respect to the cooking time of Foxtail millet indicates negative significant relationship with hydration capacity and hydration index where as positive significant relationship with crude protein (r= + 0.53*) and carbohydrates (r= + 0.47*). It was observed that cooking time of pearl millet shows positive significant relationship with its physico- chemical properties like density (r=+0.56*), hydration capacity (r=+0.26*), hydration index (r=+0.19*), swelling capacity (r=+0.24*), swelling index (r=+0.33*), crude protein (r=+0.51*) and crude fibre (r=+0.35*) respectively. Further, with respect to cooking time of Barnyard Millet indicates negative significant relationship with density, swelling capacity and swelling index where as positive significant relation with its ash (r=+0.23*) content. However, the cooking time of little millet shows negative significant relationship with swelling capacity and swelling index. Further, cooking time of proso millet indicates positive significant relationship with total carbohydrates (r=+0.39). The cooking time of sorghum revealed there was a positive significant relationship with density (r=+0.63*), hydration capacity r=+0.27*), swelling capacity r=+0.31*), crude protein (r=+0.45*), total carbohydrates (r=+0.49*) and crude fibre (r=+0.29*) where as negative significant relationship with hydration index (r=- 0.17*).

Finding from the above study clearly indicates that increases in the cooking time of finger millet increases its density, crude protein and crude fibre content and decreases its hydration capacity and hydration index. Further, increases in the cooking time of kodo millet decreases its hydration index, swelling capacity and swelling index. With respect to foxtail millet when increases the cooking time decreases in the hydration capacity, hydration index and increases in crude protein and total carbohydrates content. Pearl millet shows increases in cooking time increases its physico-chemical properties. With respect to sorghum when increases cooking time increases its protein, carbohydrates and crude fibre content.

4. Conclusion

The present study concluded that all the millets contain good source of protein, fibre and had low in fat content. Among the selected millets finger millet, pearl millet and sorghum were 80-90% germinated. Hence, various innovative products may be developed to suit the consumer needs and also to prevalent non communicable diseases.

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