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Physical and cooking properties of rice and barnyard millet varieties

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Abstract

Study of physical and cooking properties provides valuable information on grain quality, which has bearing on its final product. Results of physical properties revealed that the thousand-kernel weight (g), thousand kernel volume (ml), bulk density (g/cc) and hydration capacity (g) of barnyard millet varieties were 3.18, 4.07, 0.80 and 0.50 for PRJ-1 variety and 2.75, 3.93, 0.68 and 0.52 for local cultivar. For rice varieties, the above-mentioned properties were 13.75, 9.53, 1.43 and 1.31 for Swarna variety and 11.38, 7.96, 1.42 and 1.23 for Mahsuri variety. The results on cooking quality of grains reveal that swelling power (g/g), water uptake ratio, increase in weight after cooking (%), solid loss (%), cooking time (minutes), amylose content (%) and gelatinization temperature (^{o}C) of barnyard millet samples PRJ-1 variety and local cultivar were 2.82, 2.19, 119.6, 4.0, 13, 20.63, 75.43 and 2.81, 2.15, 115, 4.60, 13, 19.48 and 73.29, respectively. Except swelling power (g/g), water uptake ratio and cooking time, all cooking characteristics of barnyard millet samples differed significantly. The above cooking quality parameters for rice varieties Swarna and Mahsuri were 3.23, 2.26, 123.3, 3.16, 18, 21.38, 76.30 and 3.10, 2.22, 121.6, 1.85, 17, 20.03 and 75.6, respectively.

Keywords: Barnyard millet, Rice, physical property, cooking quality.

Introduction

Food, one of the necessities of life is a broad term with numerous categories and sources. Cereals and millets are one the category of food coming from the plant source, which provides staple food for majority of the world's population and contributes towards global food security. The word cereal bring its name from the Greek goddess "Ceres" meaning the "grain giver". Cultivation of cereals require good soil, lots of rain and is grown as a main crop and are large gain crops. Cereals are rich source of carbohydrate i.e. 60 to 70 per cent and contains protein, fat and vitamins.

Millets on the other hand are most likely cultivated around 4000 years ago in Asia and in middle ages, they are among the most consumed grains in European countries. Unlikely cereals, millets can be grown in poor soil, are drought resistant i.e. their cultivation do not require much rain and water, can be grown as mixed crop and are short duration crops. Millets are small grain crops. As compared to cereals, millets have high nutritional value[1]. They are rich source of minerals as well as macronutrients. Millets are continuously gaining importance for its excellent nutritional value especially in developing countries.

Rice is one of the most important food crop worldwide, which constitutes the diet of more than half of the world's population. Rice (*Oryza sativa*) is a monocot plant seed. As compared to other cereals, consumption of rice is higher among Asians. Nutrients are present in varying amounts in different layers of rice. Barnyard millet (*Echinochloa frumentacaea*) is known by several names *viz*; Japanese barnyard millet, *Sawan, Ooda, Oodalu, Jhangora* and *Madira*. Barnyard millet grows at low inputs even under adverse climatic conditions and has an excellent rejuvenating capacity. Thus, barnyard millet is considered promising crop under adverse agro climatic conditions[2].

The importance of studying the physical and functional properties of cereals and millets is necessary for designing of equipment used for handling of grains, in their processing, transport and how they will be stored, so that the quality of the grains remain intact until it reaches the consumer. Moreover, the cooking quality also helps to determine how the moisture content affects the quality of grains.

Materials and Methods

Locale of the study: The present study has been carried out in the department of Foods and Nutrition, College of Home Science, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand.

Procurement of samples: For the present investigation, two type of samples of barnyard millet, variety PRJ-1 and local cultivar were procured from Pauri garhwal, Uttarakhand while the two varieties of rice, *Swarna* (MTU-7029) and *Mahsuri* (BPT-5204) were procured from Breeders Seed Production Center, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand.

Assessment of physical properties of barnyard millet and rice: Physical properties of grains affect cooking quality and sensory quality of the product. The following physical properties were studied.

Thousand kernel weight: Thousand kernel weight of grains was determined in triplicate One thousand sound grains were counted and weighed. Weight was recorded in grams[3].

Thousand kernel volume: Thousand kernel volume was determined in triplicates using graduated cylinder by water displacement method[4]. One thousand sound grains were counted, transferred to 50 ml measuring cylinder and 25 ml of distilled water was added to it. The cylinder was shaken slightly to ensure that no air bubble was trapped and then the seed volume was recorded as total volume minus 25 ml.

Bulk density: Bulk density was determined in triplicates. A calibrated graduated cylinder (1000 ml) was filled with tapping in standardized manner. The contents of the cylinder were weighed. The bulk density of sample was expressed as g/cc[5].

Hydration capacity: Hydration capacity was calculated as the difference in weight of seeds after soaking for 24 hours in triplicates. It was expressed as weight per gram[6].

Pericarp colour: Colour of barnyard millet and rice varieties was determined in triplicate[7]. The hues and values were matched with the chart and equivalent colour was recorded.

Evaluation of cooking quality of barnyard millet and rice: The cooking characteristics of grains form the basis for consumers choice. The cooking properties are affected by the starch and protein interaction which causes structural changes in grain and these structural changes affect flavour, texture, gelling and pasting characteristics of grain.

Swelling power: For determination of swelling power, 10 g of sample was taken in a centrifuge tube and weight of the centrifuge tube containing sample was noted. A 20 ml of distilled water was added and cooked in water bath at 100°C for 20 minutes. The cooked samples were centrifuged for 10 minutes at 4000 rpm. The supernatant was transferred to a test tube and inner sides of the centrifuge tube were weighed well after drying it well[8]. The swelling power of the sample per gram was calculated using.

Swelling power (g/g) = $\frac{W3 - W2}{W1}$ x 100

Where, W1 = sample weight, W2 = tube + sample weight before cooking, W3 = tube + sample weight after cooking

Water uptake ratio: Two grams of samples were cooked in a boiling water bath for a minimum cooking time using twenty ml of distilled water. The contents were then drained and the samples were pressed between filter papers to remove superficial water present on cooked rice. Cooked grain samples were weighed and the water uptake ratio was calculated as[9]

$$\text{Water uptake ratio} = \frac{\text{Weight of cooked cereal}}{\text{Weight of uncooked cereal}}$$

Increase in weight after cooking: A 20 g of sample was put in beaker containing 40 ml of boiling distill water and cooked till the disappearance of chalky white mass in barnyard and disappearance of opaque center in rice when pressed between two glass slides[10]. The cooked weight was recorded. The per cent increase in weight of the grains was calculated using the formula.

$$\text{Increase in weight after cooking (\%)} = \frac{(\text{Cooked grain weight (g)}) - (\text{Original dry grain weight (g)})}{\text{Original dry grain weight (g)}} \times 100$$

Solid loss: Solid loss was determined by cooking sample in boiling water bath for 20 minutes. The cooked material was strained in a beaker and the whole filtrate was transferred in a petri dish, which was kept for evaporation over a water bath. The evaporated sample was dried in an oven at 105°C for 1 hour and the solids were weighed[11].

Cooking time: Minimum cooking time was determined by parallel plates method with slight modification[12] in which 30 g sample was cooked in 60 ml of water in open pan and 5 grains were pressed between 2 glass plates after every 2 minutes until at least 90% no longer has opaque center for rice and barnyard millet cooked till the disappearance of chalky white mass when pressed between two glass slides[10].

Amylose content: Amylose was calculated by the following formula[13]

Amylose percent = A/S x C_s x V/V_1 x 100/W
A= optical density of the unknown sample, S= optical density of standard, C_s= concentration of standard, V= volume made, V_1 = aliquot taken, W= Weight of the sample in gram.

Gelatinization temperature: For determination of gelatinization temperature, one gram flour sample was weighed accurately and transferred to twenty ml tubes with screw caps. Ten ml of water was added to each sample. The samples were heated slowly in a water bath until they formed a solid gel. At complete gel formation, the respective temperature was measured and taken as gelatinization temperature[14].

Results and Discussion

Physical properties of barnyard millet and rice: Physical properties *viz;* thousand kernel weight, thousand kernel volume, bulk density, hydration capacity and pericarp colour were determined using appropriate methods.

Thousand kernel weight: Thousand kernel weight is a measure of seed size. As shown in Table-1, PRJ-1 variety of barnyard millet had significantly higher value of thousand kernel weight (3.18g) as compared to local cultivar (2.75 g).studies reported thousand kernel weight of barnyard millet as 2.43g which is in line with that of the local cultivar under study[15]. Among rice varieties *Swarna* shows significantly higher value for thousand kernel weight (13.75g) as compared to11.38g for *Mahsuri* variety of rice. Another study reported that the thousand kernel weight of rice varieties ranged between 14.0-18.5g, respectively which seems higher than the varieties taken under present study[16]. Significant difference was found between barnyard millet and rice samples for thousand kernel weight (Table 1). The reason forvariation in thousand kernel weight of grain is due to difference in its kernel density which also gives an indication of its consequent flour yield[17].

Thousand kernel volume: The thousand kernel volume of barnyard millet samples PRJ-1 variety and local cultivar differ significantly (Table-1). The value of thousand kernel volume was 4.07 ml for PRJ-1variety and 3.93 ml for local cultivar. Various studies reported thousand kernel volume of barnyard millet as 5.79[18], 1.32[19] and 2.03[15] ml. Among rice varieties thousand kernel volume of *Swarna* was significantly higher than *Mahsuri*. As depicted in Table 1 thousand kernel volume of barnyard millet varieties and rice varieties significantly differed with each other.

Bulk density: Bulk density is defined as the ratio of the mass to a given volume of a grain sample including the interistitial voids between the particles[20]. Bulk density of grain is commonly effected by excessive moisture content and insect infestation[21]. Among barnyard millet samples bulk density of PRJ-1 did not differ significantly from the local cultivar. The bulk density values being 0.80 g/cc for PRJ-1 variety and 0.68 g/cc for local cultivar. Rice samples also showed non- significant difference between bulk density values of *Swarna* and *Mahsuri*. The bulk density of *Swarna* and *Mahsuri* was 1.43 g/cc and 1.42 g/cc, respectively. It is clear from Table 1 that bulk density of barnyard millet and rice varieties differed significantly with each other.

Hydration capacity: The barnyard millet samples PRJ-1 variety and local cultivar showed non- significant difference between hydration capacity values (Table-1). Hydration capacity of PRJ-1 variety and local cultivar was 0.50 and 0.52g, respectively. Whereas among rice varieties significant difference was observed in hydration capacity values of *Swarna* (1.31g) and *Mahsuri* (1.23g). Hydration capacity of rice in one study was reported as 3.29 g[22].

Pericarp colour: Color is an important primary factor for characterization, grading, trade, and processing of grain. Among two samples of barnyard millet, pericarp colour of PRJ-1 and local cultivar was pale brown (chrome-4, value 5/7-4) and gray (chrome- 3, value 5/7-1), respectively. According to a study the colour of barnyard millet grain was olive green[10]. Both the varieties of rice *Swarna* and *Mahsuri* had white colour (chrome 0, value 5/8-1).

Cooking quality of barnyard millet and rice: The cooking characteristics of barnyard millet and rice varieties have been presented below.

Swelling power: Differences in proportion of crystalline and amorphous areas in the starch granules are major cause of variation in water binding capacity of grain. Starches containing higher proportion of amorphous material are responsible for absorbing more water due to presence of more water binding sites[23]. Barnyard millet samples showed non-significant difference in their swelling power. The swelling power of PRJ-1variety and local cultivar was 2.82g/g and 2.81g/g, respectively (Table-2).

Among rice varieties the value of swelling power was 3.23g/g for *Swarna* significantly higher than *Mahsuri* (3.10g/g). A study done by Ali *et al.* showed that the swelling capacity of two rice varieties Jhelum and kohsar was 9.23 and 8.67g/g, respectively. It was reported that swelling power of grain depends mainly on amylose and amylopectin proportion of starch but also on presence of some non-carbohydrate substances like lipids. Lipid acts as inhibitor in swelling power of grain[24]. Significant difference was found between swelling power of barnyard millet varieties and rice varieties.

Water uptake ratio: Water uptake ratio of PRJ-1 and local cultivar was 2.19 and 2.15, respectively. Non- significant difference was observed between water uptake ratio of rice varieties *Swarna* (2.26) and *Mahsuri* (2.22). Comparison of cooking quality of barnyard millet and rice varieties suggest that PRJ-1 variety of barnyard millet and *Mahsuri* variety of rice showed non significant difference for water uptake ratio (Table-2) but local cultivar of barnyard millet differed significantly with that of rice varieties.

Increase in weight after cooking: Importance of increase in weight after cooking also represents the economic value of grain. Among barnyard millet samples increase in weight after cooking was significantly higher in local cultivar. Increase in weight of PRJ-1 and local cultivar after cooking was 119.6 and 115 per cent, respectively. For rice varieties increase in weight after cooking was 123.3 per cent for *Swarna* which was significantly higher than *Mahsuri* (121.6%) (Table-2). Rice varieties had significantly higher value for increase in weight after cooking as compared to barnyard millet varieties.

Solid loss: Perusal of Table-2 indicates that among barnyard millet varieties the solid loss was significantly higher in local cultivar. Solid loss in PRJ-1 variety was 4.0 per cent whereas in local cultivar it was 4.6 per cent.

Among rice varieties the solid loss (3.16%) in *Swarna* was significantly higher than *Mahsuri* (1.85%). According to

Thomas *et al*, the solid loss of rice varieties ranged between 3.17-6.43 per cent. Solid loss was significantly higher in barnyard millet varieties as compared to rice varieties.

Cooking time: Cooking is important as it provides palatability to the food, prevents many food borne illnesses that would otherwise occur if the food is eaten raw[25].

Among barnyard millet the cooking time of both samples was 13 minutes**.** For rice varieties the cooking time of *Swarna* was 18 minutes whereas for *Mahsuri* it was 17 minutes as shown in Table-2. In astudy reported that cooking time of rice varieties ranged between 10-31 minutes. Cooking time of rice varieties was significantly higher than barnyard millet varieties[26].

Amylose: Starch granule is made up of two polymers *viz;* amylose and amylopectin. Amylose is linear molecule which consists of α-(1,4)-linked D-glucopyranosyl units while amylopectin is highly branched polymer made up of α-(1,4)-linked D-glucopyranosyl units which are joined together with α-(1,6) linkages. Classification of rice is based on its amylose content. Rice containing 0-2 per cent amylose is considered waxy rice whereas rice containing 2-12 per cent, 12- 20 per cent, 20 – 25 per cent and 25-33 per cent of amylose are considered very low amylose, low amylose, intermediate and high amylose containing rice[27]**.**

Amylose content of PRJ-1 variety (20.63%) of barnyard millet was significantly higher than local cultivar (19.48%) (Table-2). Amylose content is the major factor affecting cooking quality (Juliano, 1971). It helps in determining the stickiness of cooked grains. Among two rice varieties, the amylose content depicts significant difference, which was 21.38 per cent and 20.03 per cent in *Swarna* and *Mahsuri*, respectively. Amylose content of barnyard millet varieties differed significantly from rice varieties.

Gelatinization temperature: Cooking time and molecular size of starch fraction are factors related to gelatinization temperature of grain. But gelatinization temperature is directly related to amylose content of grain. Higher the amylose content higher will be the gelatinization temperature[28]. Furthermore, the higher the gelatinization temperature the longer the grain takes time to cook as grain containing more amylose content absorbs more water.

The gelatinization temperature of two barnyard millet samples PRJ-1 and local cultivar was found to be 75.43 and 73.29^{0}C, respectively (Table-2). PRJ-1 had significantly higher gelatinization temperature than local cultivar. Among rice varieties *Swarna* and *Mahsuri* the gelatinization temperature was found to be 76.30 and 75.6^{0}C, respectively. Non-significant difference was observed in gelatinization temperature of rice varieties.

Comparison between barnyard millet varieties and rice varieties for gelatinization temperature suggest that PRJ-1 variety of barnyard millet had non-significant difference with both rice varieties for gelatinization temperature whereas local cultivar showed significant difference with both rice varieties (Table-2 and Figure-2).

Table-1: Physical properties of barnyard millet and rice varieties.

Physical properties	Barnyard millet		Rice		S.Em	CD at 5%
	Variety PRJ-1	Local Cultivar	Variety *Swarna*	Variety *Mahsuri*		
Thousand kernel weight (g)	$3.18^a \pm 0.02$	$2.75^b \pm 0.04$	$13.75^c \pm 0.04$	$11.38^d \pm 0.09$	0.03	0.10
Thousand kernel volume (ml)	$4.07^a \pm 0.04$	$3.93^b \pm 0.06$	$9.53^c \pm 0.08$	$7.96^d \pm 0.07$	0.03	0.12
Bulk density (g/cc)	$0.80^a \pm 0.2$	$0.68^{ab} \pm 0.01$	$1.43^c \pm 0.01$	$1.42^{cd} \pm 0.03$	0.08	0.27
Hydration capacity (g)	$0.50^a \pm 0.03$	$0.52^{ab} \pm 0.15$	$1.31^c \pm 0.03$	$1.23^d \pm 0.12$	0.01	0.06

All results are mean±SD for three individual determinations: S.Em – standard error of mean, CD – critical difference, a,b,c,d= significant difference between samples of barnyard millet and rice for physical characteristics, ab= non significant difference between PRJ-1 and local cultivar of barnyard millet, cd= non significant difference between Swarna and Mahsuri variety of rice.

Table-2: Cooking quality of barnyard millet and rice.

Cooking characteristic	Barnyard millet		Rice		S.Em	CD at 5%
	Variety PRJ-1	Local cultivar	Variety *Swarna*	Variety *Mahsuri*		
Swelling power (g/g)	$2.82^{a}\pm0.02$	$2.81^{ab}\pm0.04$	$3.23^{c}\pm0.09$	$3.10^{d}\pm0.02$	0.01	0.04
Water uptake ratio	$2.19^{a}\pm0.01$	$2.15^{ab}\pm0.02$	$2.26^{c}\pm0.02$	$2.22^{ad,cd}\pm0.04$	0.01	0.06
Increase in weight after cooking (%)	$119.6^{a}\pm0.02$	$115^{b}\pm0.01$	$123.3^{c}\pm0.02$	$121.6^{d}\pm0.02$	0.04	0.15
Solid loss (%)	$4.0^{a}\pm0.01$	$4.60^{b}\pm0.01$	$3.16^{c}\pm0.02$	$1.85^{d}\pm0.01$	0.08	0.02
Cooking time (min)	$13^{a}\pm0.03$	$13^{ab}\pm0.15$	$18^{c}\pm0.03$	$17^{d}\pm0.01$	0.01	0.05
Amylose (%)	$20.63^{a}\pm0.03$	$19.48^{b}\pm0.02$	$21.38^{c}\pm0.02$	$20.03^{d}\pm0.01$	0.01	0.04
Gelatinization temperature (^{0}C)	$75.43^{a}\pm0.04$	$73.29^{b}\pm0.03$	$76.30^{ac}\pm0.06$	$75.6^{ad,\ cd}\pm0.03$	0.41	1.34

All results are mean±SD for three individual determinations: S.Em – standard error of mean, CD – critical difference, a,b,c,d= significant difference between samples of barnyard millet and rice for cooking characteristics, ab= non significant difference between PRJ-1 and local cultivar of barnyard millet, ac=non significant difference between PRJ-1 variety of barnyard millet and Swarna variety of rice, ad= non significant difference between PRJ-1 variety of barnyard millet and Mahsuri variety of rice, cd= non significant difference between Swarna and Mahsuri variety of rice.

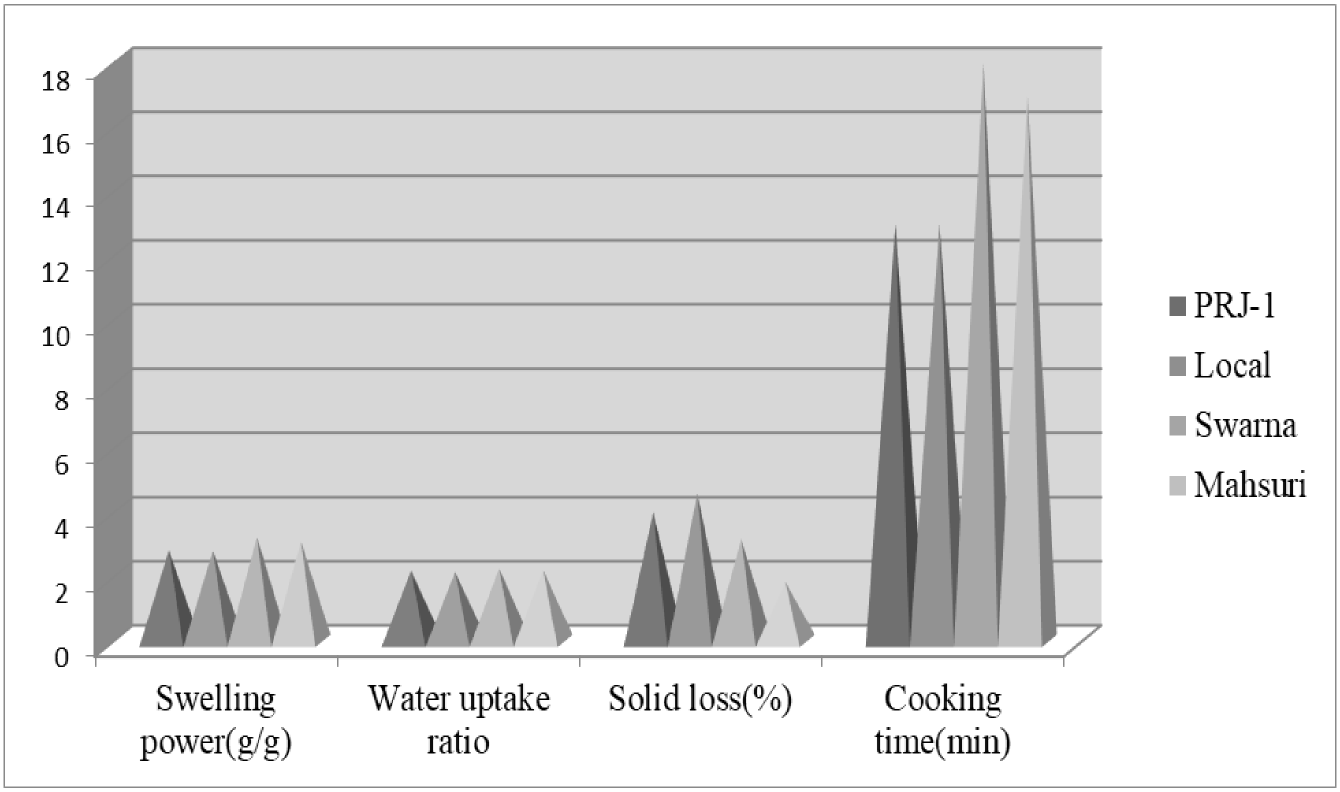

Figure-1(a): Cooking characteristics of (PRJ-1 variety and local cultivar) and rice (variety Swarna and Mahsuri).

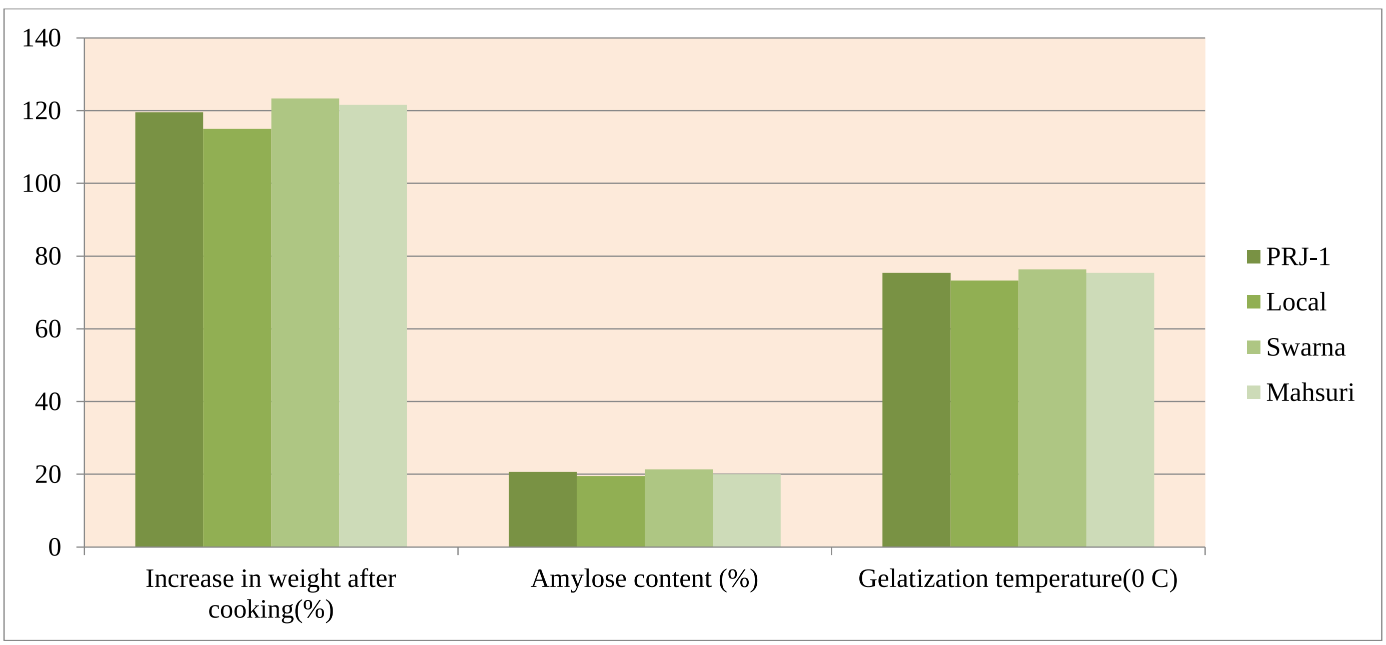

Figure-1(b): Cooking characteristics of barnyard millet (PRJ-1 variety and local cultivar) and rice (variety Swarna and Mahsuri).

Conclusion

Physical properties of grain is important criteria as it influences the cooking and sensory quality of grains and both physical and cooking characteristics are important with respect to product development. Cooking quality is influenced by many factors such as cooking method, cooking time, bulk density of grains storage condition etc. Various research studies indicate that cooking quality is directly related to the physical and chemical characteristics of the starch molecules i.e. amylose and amylopectin ratio, gelatinization temperature and consistency of gel. Thus economic value of grains depends on its cooking quality parameters.

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