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Preparation and functional properties of noodles prepared from raw and hydro-thermally processed rice

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ABSTRACT

Attempts have been made to prepare noodles from brown and low-polished rice. Some of the functional properties of these rice noodles along with sensory profile of the respective raw forms are discussed in this paper. Water absorption index was low in noodles compared to their native form but water soluble index was reverse. Total and soluble amylose and thiamine reduced in respective noodles compared to their respective native form. Solid loss was less in steamed rice noodles compared to their native. Rice had low solubility index but noodles showed 30 to 50% higher value. Gelatinization temperature decreased with increase in polish. Peak viscosity, hot paste viscosity was high for raw rice compared to steamed brown rice. Cold paste viscosity increased with increase in degree of milling, break down was least in steamed brown rice. Steamed brown rice noodles had high viscosity compared to other types of noodles like under milled, steamed under milled and steamed highly polished rice noodles. Sensorial test of steamed brown rice noodles were better compared to raw rice noodles.

Key words: *raw, processed rice noodles, preparation, functional properties*

Rice is very popular in Asia, especially China, Indonesia, Bangladesh, Pakistan, Sri Lanka and India and is used as staple food. When the actual extraction rates of the cereals are considered, rice is calculated to produce more food energy per hectare than other cereals (Lu and Chang, 1980). The average recovery of brown (unpolished) rice from paddy is about 80% and white rice (head) is about 60% along with about 10% of brokens. Out of the total production about 10% is used for the production of rice processed products (flaked, expanded and popped), beside these, there are several other products with combination of pulses like black gram idli, dosa and vada etc. Rice has particular properties which makes it different from other grains. Medium grain low amylose rice (12-20%) is used in making baby foods; breakfast cereals and adjuncts in brewing. Intermediate-amylose rice (20-26%) is used in making canned soups and for fermented rice cakes. High amylose rice's (more than 25%) are used for extruded products like noodles. In addition to long and medium–grain, other rice commercially available are waxy (low amylose), scented, lengthy varieties, canner's grade rice, low gelatinization temperature types and wild varieties.

Pasta food products are prepared by the use of cereals like rice, wheat, maize, rye etc. Pasta includes macaroni, spaghetti and vermicelli. Noodles are generally prepared from soft wheat flour by the process of sheeting and cutting or by the help of extrusion followed by cutting. Vermicelli is solid rods of diameter between 0.5 and 1.25 mm and length between 25 to 250 mm. The pasta products should be free from mould, insect infestation, any type of contamination and cracks etc. According to Indian standard (IS: 1485-1976), the material should have around 12% moisture, 0.7% total ash, 0.05% as acid insoluble ash, total solid loss is 8%. Cereals like rice, and isolated starches do not contain gluten, like in wheat, and therefore require gelatinization during processing as a binder (Juliano and Sakurai, 1985) so, the manufacturing methods depend upon the presence or absence of gluten. Wheat flour noodles are produced by sheeting and rolling, where as other types are typically processed by extrusion or batter cooking. There are two main methods for the preparation of rice noodles, first by extrusion, vermicelli types and second, by sheeting of batter to produce sheets and flat type of noodles. Different processing operations have been done in which hydrothermal treatment is one, in this semi-crystalline structure of the starch is converted into amorphous mass due to the swelling of starch. In this process some physical, chemical and organoleptic changes occurs in the rice. Considerable work has been carried out on cereal noodles at Central Food Technological Institute, Mysore, India during 1990s. On laboratory scale rice, maize, finger millet (ragi), sorghum (jowar), pearl millet (bajra), foxtail millet (navane) and little millet (samai) have been done and patented (Sowbhagya and Ali, 1996,1998, 1999, 2000).

Due to several physico-chemical properties of rice, it is used in a variety of products. Brown rice is produced after dehusking of paddy. Brown rice has several important properties as it is rich in Ca, phosphorus, iron, sodium and vitamins like thiamine, riboflavin and niacin. Due to these properties, in recent time the use of brown rice has been increased in the preparation of different products. In this paper, attempts have been made to prepare noodles from rice polished to different degrees as well as from steamed rice and their physico-chemical properties have been reported.

MATERIALS AND METHODS

Rice cv IR–64 harvested during Dec. 2004 and stored at room temperature (30 ± 2^0 C) for about a year was used in the study. Pure potato amylose (standard amylose preferably from M/S ICN Biochemical's, USA) was procured. Paddy was cleaned and de hulling was done with the help of rubber roller Sheller (Satake rice machine, Japan). After removal of husk, brown rice was used for the preparation of under milled as well as high polished rice. Similar operations were done for steamed paddy of the same variety. These two types of rice, raw and steamed were further ground with the help of flourmill (Universal Domestic Flour Mill, Mysore).

Moisture was determined as per the IS: 1485-1976, specification for macaroni, spaghetti and vermicelli. Weigh accurately 5 g of the prepared sample in a suitable moisture dish, made of porcelain, silica or platinum, previously dried in an air oven and weighed. The dish was placed in an air-oven maintained at 105±2°C for five hours. The dish was cooled in a desiccator and weighed with the lid on. It was heated again at 105±2°C in the air oven for 30 minutes. The dish was cooled in the desiccator and weighed. This process of heating for 30 minutes, cooling and weighing was continued till the difference in mass between two successive weighing is less than one milligram. The lowest mass and moisture content was estimated. Equilibrium moisture content was determined by the method used was as described by Indudhara Swamy *et al*, 1971. The surface colour of noodles in terms of colour differences (δE) and yellow indices (Y) (E-313) was measured using Ultra Violet-Visible recording spectrophotometer (Minolta spectrometer CM-3500d). Test conditions were: Colour measuring system Hunter lab.: Illuminator used C; Angle of Observance 2°. A standard white tile made from barium sulfate (100%) was used as a perfect white object for setting instrument with illuminant, samples were placed in the sample holder and readings were recorded. Water absorption index and water solubility index was determined as per the method of Anderson *et al*. (1969). Noodles were powdered by the use of grinder and sieved by using 60-mesh sieve. Powdered noodles (2.5gram) were taken in a previously tarred centrifugation tube, to which 30 ml of distilled water was added and continuously stirring was carried out for 30 mins. at room temperature. This was centrifuged at 3500 rpm for 10 mins. The supernatant was carefully decanted into a previously weighed petri-plate, evaporated to dryness on a water bath and eventually dried at 105°C in air oven for 3 hrs, and weight was noted. Water solubility index (WSI) was calculated using the equation:

WSI (%) = Dried solids in supernatant x100/ 2.5 (weight of sample).

Sediment in the centrifuge was weighed and WAI was calculated as follows:

WAI (g/g) = Weight of gel / Weight of sample (2.5gram)

Swelling and solubility of these samples were determined according to the procedure described by Vasudeva Singh *et al.* (2000). Thiamine content in the samples was estimated as per the procedure of Subba Rao and Bhattacharya, 1966. Amylose equivalent was estimated as per the procedure of Sowbhagya and Bhattacharya, 1979 and Soluble amylose equivalent was estimated as per the procedure of Shanthy *et al*, 1980. As per the procedure of Indian Standards, but with slight modifications were done during the total solid loss measurement, instead of 250 ml, 50 ml of water was taken in a lipless beaker and heated over the hot plate to boiling. Put 5 gram instead of 25 gram of the material (~1 cm length) and after that stirred with the help of glass rod. Cooking was carried out and intermittently stirring was done. At the end of 10 minutes, the supernatant was drained. The filtrate was taken out into a tared petridish and then evaporated to dryness on a water bath. Transfer the Petri dish to a hot air oven at 105°C and then dried up to a constant mass and the solids in the gruel was calculated with the following formula:

Total solids in gruel (%) = weight of the dried mass x 100 / weight of the sample.

Total ash was estimated as per the procedure described in the Indian Standard: 1485-1976. Viscography was carried out in a Brabender Viscograph type 801202 (Duisburg, FRG) fitted with a 700-cmg-sensitivity cartridge. The method followed was as per Halick and Kelly (1959) and Koh and Singh (2009). The following conditions were kept constant: rpm 75; rate of heating as well as cooling, 1.5°C/min; highest temperature to which heated was 95°C and temperature to which finally cooled was 50°C. the following other conditions were used for the standard runs; total slurry weight 500 g: thermo regulator setting at beginning of heating, 30°C: time of heating at 95°C for 20 min and the thermo regulator setting at beginning of cooling at 95°C and cooled to 50°C. From the Viscograms following parameters were read: gelatinization temperature, peak viscosity, and hot paste viscosity, cold paste viscosity. Other parameters calculated from these values were break down (BD) (difference between PV and HPV): set back which is the difference between CPV and PV: total set back is the difference between CPV and HPV, and relative break down is the ratio of break down to total set back. The concentration of the slurry maintained was 10 % (d.b).

Evaluation of different type of cooked noodles for various sensory characteristics was carried out. Sensory evaluation was done by a group of nine panelist and the attributes studied were: colour and appearance, tenderness, moistness, stickiness, mouth feel, taste and over all quality.

The main steps for the noodles preparation were as follows -

Raw material
↓
Cleaning
↓
Hydration
↓
Dehydration
↓
Size reduction and grading
↓
Additives and mixing
↓
Hydrothermal treatment
↓
Dough Preparation
↓
Extrusion
↓
Post extrusion treatment
↓
Drying
↓
Packaging Cereal / millet noodles

RESULTS AND DISCUSSION

The moisture content of raw paddy (IR-64) was ~ 11 %, while that of steamed one was ~ 14 %. (w.b). The husk % was same in both samples (~ 21%). The chaffed material was less in the case of steamed one (0.8%) (Table 1). Head rice in brown rice was high in raw paddy by about 6% compared to the steamed one, whereas broken percentage was high in the case of steamed rice. In under-milled rice, where lot of nutrients have been retained, the head rice content was high by about 20% and brokens were less by about 10% compared to the steamed one. In highly polished rice, similar observations were seen. Under similar conditions of polishing, the degree of polish was high in the case of steamed paddy.

The moisture content of different raw rice flour was higher than that of steamed samples which was about 2 to 3 % (Table 2). It was seen that the moisture content of steamed noodles were higher than the noodles prepared from raw rice. All the raw rice noodles had almost same moisture content. Steamed rice noodles

Table 1: Milling data of the raw and steamed paddy

Type of paddy	Brown rice		Under milled rice			Highly polished rice		
	Head rice (%)	Broken (%)	Head rice (%)	Broken (%)	Degree of polishing(%)	Head rice (%)	Broken (%)	Degree of polishing(%)
Raw paddy	87.9± 1.0	11.5±0.8	90.9± 2.0	10.3± 1	3.4± 0.25	86.5± 2	10.2± 1	5.8± 0.2
Steamed paddy	82.0±1.5	17.4±0.7	90.8±1.5	0.8± 0.05	3.3± 0.3	78.0± 2	20.2± .5	6.5± 0.3

have shown higher moisture probably due to retrogradation of starch during steaming and drying of paddy, other processing steps where hydrothermal treatment might have played role. The moisture content of steamed rice noodle powder samples were higher as compared to raw rice noodle. This may be due to higher surface area in the powder form along with the hydrothermal process involved while making noodles, which makes evaporation easy and hence lower values in raw as well as steamed compared to noodles strands.

Table 2. Moisture Content of Rice Flour, Noodle and Noodle powder (% wb)

Material	Rice flour	Noodle	Noodle powder
Brown rice	11.2	7.5	6.3
Steamed brown rice	8.2	11.1	7.3
Under milled rice	11.0	7.3	6.3
Steamed under milled rice	8.1	12.0	7.6
Highly polished rice	9.1	7.6	6.3
Steamed highly polished rice	8.3	9.3	7.5

The equilibrium moisture content (EMC) of raw as well as steamed rice samples were more or less same for all types of rice, though around 1 to 2 % excess were shown in the steamed rice samples (Table 3). The EMC of noodles were very high (~73% as) as they have been prepared with number of processing steps which includes soaking, size reduction, hydrothermal treatment, extrusion, again hydrothermal treatment, drying where mainly retrogradation takes place in the process and hence the EMC was high. Noodles prepared from steamed rice samples especially raw highly polished rice, the value was little high. Otherwise all values remained almost same.

For colour measurement of the samples prepared from raw and steamed rice as well as respective noodles in powder form were used in Hunter Colour Measuring System. In this system four values

Table 3. Water Absorption Index , Water Solubility Index, Thaimine, Amylose, Soluble amylose and ash in different forms of rice before and after steaming

Type of Rice	Equilibrium moisture content (%)	Water Absorption Index(g g^{-1})	Water Solubility Index(g g^{-1})	Thiamine µg $100g^{-1}$	Amylose (%)	Soluble amylose (%)	Ash (%)
Brown rice	27.3±0.3	3.2±0.06	3.55± 0.09	496±36.2	19.22±0.11	13.06±0.21	1.25
Brown rice noodle	74.5±0.2	1.1±0.04	4.80±0.30	339±8.08	16.10±0.17	10.40±0.20	2.52
Under milled rice	28.3±0.3	2.9±0.19	2.96±0.05	346±22.5	20.60±0.21	13.93±0.12	1.02
Under milled rice noodle	73.1±0.3	1.0±0.08	4.36±0.13	266±2.52	18.18±0.23	9.53±0.30	2.48
Highly polished rice	28.0±0.2	2.4±0.13	2.38±0.09	242±1.00	26.35±0.13	14.07±0.22	0.31
Highly polished rice noodle	75.8±0.9	0.9±0.01	4.10±0.21	246±2.31	21.47±0.50	9.31±0.30	2.28
Steamed brown rice	28.2±0.1	3.7 ±0.04	3.04 ±0.10	421±17.4	20.72±0.19	12.22±0.25	2.53
Steamed brown rice noodle	73.4±0.9	1.1± 0.26	7.45± 1.62	288± 0.57	17.25±0.24	10.62±0.40	2.30
Steamed under milled rice	30.0±0.1	3.3±0.01	2.56±0.03	255±5.80	21.20±0.26	12.30±0.30	2.48
Steamed under milled rice noodle	73.7±0.1	0.9 ±0.24	4.74 ±0.78	245±3.00	20.34±0.57	10.38±0.30	1.90
Steamed highly polished rice	29.2±0.9	3.3± 0.01	2.39± 0.06	299± 16.2	21.44±0.48	12.49±0.38	0.41
Steamed highly polished rice noodle	74.9±0.1	0.5±0.03	4.72±0.18	247±1.73	20.59±0.40	8.62±0.20	1.68

were obtained. They were 'L', which signifies the lightness; 'a' which signifies red to green colour, 'b' indicates the yellow to blue colour, and δE denotes the total colour difference or overall change in the colour. The L values of raw rice samples increased with increase in degree of polish. The range observed was ~ 83 to ~ 90 (Table 4). The 'a' increases with increase in degree of milling, but that of 'b' values decreases with increase of degree of polish. The total colour values i.e. "E, decreased from brown rice to highly polished rice (i.e. ~10 to ~ 3), indicating the increase in whiteness with increase in the degree of polish. Values for raw noodle samples, brown rice was dull in appearance as L value was ~ 65. The colour improves in under milled rice noodle and further improves in highly polished rice noodles, where the values were ~ 72 and ~ 78, respectively. The value of 'a' and 'b' were comparatively high in the noodles, compared to raw samples, because of the processing steps. These values decreased in the noodles.

In steamed rice the L value increases from brown to highly milled rice i.e from ~83 to ~88 and total colour values (δE) decreased from steamed brown rice to steamed highly polished rice ~11 to ~6, indicating the increase in brightness with increase in degree of polish (Table 4). The L and δE values were inversely proportional. With respect to 'a' value, it was high for steamed brown rice and decreased with increase in degree of polish. Similar observations were with 'b' value. Same observations were noticed in noodles prepared from steamed rice samples. Compared to rice, the values were less in noodles. The values were ~ 72 to ~ 77 in the case of L for noodles. However the total colour value decreased from ~ 22 to ~ 16 indicating increase in brightness of the product prepared. Similarly in noodles, the values of 'a' and 'b' decreased with the product prepared from steamed rice samples.

In the case of raw rice, brown rice showed highest water absorption index (WAI) followed by under-milled rice and highly polished rice (Table 3).

Table 4. Colour of different raw rice and steamed rice and their respective noodles

Type of Rice	L	a	b	δE
Brown rice	83.3± 0.05	0.3±0.03	7.4±0.02	10.1±0.04
Brown rice noodle	65.5±0.02	0.9±0.03	9.9±0.06	27.0±0.01
Under milled rice	86.2±0.08	0.5±0.04	6.1±0.06	67.1±0.09
Under milled rice noodle	71.9 ± 0.11	0.36 ± 0.02	9.31 ± 0.04	20.71 ± 0.09
Highly polished rice	90.2±0.18	0.8±0.04	3.7±0.08	3.2±0.05
Highly polished rice noodle	78.4±0.02	0.8±0.03	7.3±0.02	13.9±0.02
Steamed brown rice	83.2± 0.07	- 0.1±0.04	8.7±0.09	11.1±0.08
Steamed brown rice noodle	72.4±0.04	-0.3±0.02	12.9±0.02	22.03±0.02
Steamed under milled rice	86.8±0.03	-0.6±0.04	6.60±0.07	7.1 ± 0.05
Steamed under milled rice Noodle	75.8±0.09	-0.6±0.045	10.8±0.04	18.0±0.10
Steamed highly milled rice	88.3±0.13	-0.7±0.03	5.6±0.04	5.5±0.02
Steamed highly milled rice Noodle	77.3±0.11	–0.7±0.05	9.7±0.15	16.2±0.14

Even the δ E values for the raw rice noodles, which was highest for brown rice and the value decreased up to ~14 in highly polished rice noodles (from about 27 to about 14). This implies that in the processed rice samples, the intensity of brightness was low in brown rice noodles and high in highly polished rice noodles, which were quite opposite to the respective raw rice samples. Brightness of noodles was less because of various processing steps, where browning reaction takes place while processing.

After steaming the water absorption index increased to some extent in all three types of rice compared to respective raw rice. The increase appeared to be very high in the case of highly polished rice, indicating higher absorption of water by the processed starch granules in steamed highly polished rice which may be because of slight retrogradation during steaming and drying.

In the case of noodles, the absorption of water reduces drastically in raw as well as steamed in all three different forms of rice. Possibly this may be due to the presence of fat in all three types of noodles. Even steamed highly polished rice noodles shows very little water absorption index, which was almost 50% less than raw highly polished rice noodles.

In raw rice, the solubility index decreased continuously from brown to highly polished rice. The decrease was to an extent of 16% in under milled rice and about 20% in highly polished rice (Table 3). Reduction in solubility index continued even in steamed rice samples. From steamed brown rice to under milled rice the reduction was about 16% and that from steamed under milled rice to steamed highly polished rice, the reduction was around 7%. In the case of noodles (raw and steamed) solubility index increased from their respective rice samples. In raw rice noodle, the solubility index was high in brown rice noodles and the value decreased to a lesser extent in under milled rice as well as highly polished rice noodles. In steamed brown rice noodles this index was very high i.e. about 7.5%, where as in steamed under milled rice noodles, it was low i.e about 4.7% and remained same in steamed highly polished rice samples. These results indicated that at room temperature, the solubles were very high in steamed rice noodles indicating the high leaching of the linear molecules from the system.

In the raw rice, these Solubility index values were less but in steamed rice the values were low, compared to the former, indicating that the leach out at room temperature were less in hydro thermally treated rice grains. However in the noodles the value were high compared to their respective grains. In the case of raw rice noodles, even at room temperature, while stirring, some amount of leach out occurred which was because of the linear components present in the respective starch granules were coming out or leaching out. In the case of steamed rice noodles, the quantity of leach out further increases, where we observe, the noodles had the property to leach out the linear components from their respective processed starch granules to a higher extent.

The most important property of starch or flour in commercial application is its ability to swell and to produce a viscous paste when heated in water (Leach, 1965). The values of swelling power were less in the case of raw rice flour samples compared to the steamed samples (Table 5). The swelling power of raw brown rice was higher compared to other two forms of raw rice. However, in steamed rice the values were almost same for brown and under-milled one, but for the highly polished one it decreased by one i.e. ~ 13 to ~ 12.

Generally solubility indicates the leach out of linear and lengthier chains of amylopectin molecules while cooking of the rice flour. The data indicated both in raw as well steamed from brown to under milled rice, the solubility decreases whereas that of highly polished rice increased by about 2% in raw and about 4% in steamed rice, compared to their respective under milled rice (Table 5).

Table 5. Swelling power and solubility of different rice before and after steaming

Type of Rice	Swelling power(g g^{-1})	Solubility (%)
Brown rice	12.30 ± 0.42	32.27± 0.61
Under milled rice	10.98 ± 0.68	23.58± 1.66
Highly polished rice	11.50 ± 0.70	25.04±1.19
Steamed brown rice	13.56± 0.24	31.29±0.56
Steamed under milled rice	13.23± 0.13	26.83±0.76
Steamed highly polished rice	12.29± 0.66	30.41±1.85

Thiamine content of raw brown, under milled and highly polished one were 496,313, and 242 µg $100g^{-1}$, respectively. After steaming the values were 421,254 and 259 µg $100g^{-1}$, respectively. Because of steaming in brown rice the value was decreasing, which was also true in under milled and highly polished rice (Table 4). Thiamine content decreased in the noodle of different types of raw rice. Drastic reduction was seen in the brown rice as well as under milled rice noodles in the case of raw rice. However in steamed brown rice noodles the values decreased but in steamed under milled rice noodles the values remained almost same. In the noodles of highly polished rice of raw as well as steamed one, the values did not change much indicating the less effect of highly polished rice as well as steaming on thiamine contents after noodle preparation.

The total amylose values were marginally higher in the case of steamed samples as compared to the unsteamed samples (Table 4). There was around 2% increase observed. While in the case of steamed rice flour samples these values were more or less same.

Total amylose values were decreased from raw rice to their respective noodles. This may be due to the various process steps involved during noodle preparation. However the values are marginally higher in the case of steamed rice noodle samples. In the case of steamed polished rice noodles, there was decrease in total amylose content, probably the linear molecules in starch granules had undergone severe process treatment which might have broken the linear chains and might have not available for amylose estimation. Soluble amylose decreased in brown, under-milled and highly polished rice samples after steaming (Table 4). Soluble amylose in the raw brown rice noodles as well as steamed brown rice noodles remained almost same. However, in under-milled rice noodle and steamed one, there was marginal increase in soluble amylose. In highly polished rice noodles the values reduced marginally indicating the effect of polishing as well as steaming. The severe processing treatment makes the rice / noodle to become hard, by which starch granules become hard, and hence leaching of the linear molecules may be least.

Table 6. Total solid loss in different forms of noodle

Type of Rice	%
Brown rice noodles	10.46±0.15
Under milled rice noodle	13.05±0.05
Highly polished rice noodle	12.20±0.21
Steamed brown rice noodles	7.51±0.36
Steamed under milled rice noodle	9.26±0.08
Steamed highly polished rice noodle	9.23±0.15

The solid loss was more in the in the case of un-steamed noodle samples as compared to that from steamed one. In noodles from raw rice sample the total solid loss was high in under milled rice noodles (~13%) followed by noodle from highly polished rice and lowest in noodles from brown rice samples (Table 6). These values were somewhat high on comparison with BIS norms. The values for the noodles prepared from steamed rice were with in the limits of BIS specification. Lowest solid loss was observed for noodles from steamed brown rice i.e. ~ 7.5%. However the values were around 9% for both the noodles prepared from steamed under milled rice as well as steamed highly polished rice. The values are shown in the following Table 4. In the case of raw samples, the ash content in brown rice was 1.25%. In under milled rice, it decreased by 18% while in highly polished rice it decreased by 75% as compared to brown rice. In steamed samples it was more or less same in the case of brown as well as under milled rice while in the highly polished rice the value reduced to 0.4%. The total ash content increased in the noodle samples, which were either from raw or from steamed rice samples. This may be due to the addition of salts while preparing the noodles.

As per the procedure of Juliano, B. O. and Pascual, C. G. (1980), it has been noted that at 20% concentration, gelatinization temperature could be measured accurately. Even they had informed that at 20% concentration, the gelatinization measured will be 3°C less than measured at 10% concentration. Hence the gelatinization temperature values in the above table have been shown 3°C less than what has been read from the Brabender Viscograms. Gelatinization temperature was higher for under milled rice (80°C) but almost same for brown and highly polished rice (Table 7) Peak Viscosity was 980, 910, and 1330 BU for brown, under milled and highly polished rice, this was due to the high swelling of starch granules in the highly milled rice. However because of lower degree of polishing the peak viscosity was less in under milled rice as well as brown rice, where the brown rice constituents might have hindered the swelling of starch granules.

Table 7. Viscosity data of different raw and steamed rice in Brabender Units

Type of rice	GT(C°)	PV	HPV	CPV	BD	SB	SB_t	BD_r
Brown rice	73.5	980	650	1360	330	380	710	0.460
Under milled rice	80	910	610	1410	300	500	800	0.375
Highly polished rice	73	1330	1170	2000	160	670	830	0.192
Steamed brown rice	80	510	470	1040	40	530	570	0.070
Steamed under milled rice	78	920	730	1450	190	530	720	0.260
Steamed highly polished rice	76	1250	900	2080	350	330	1180	0.297

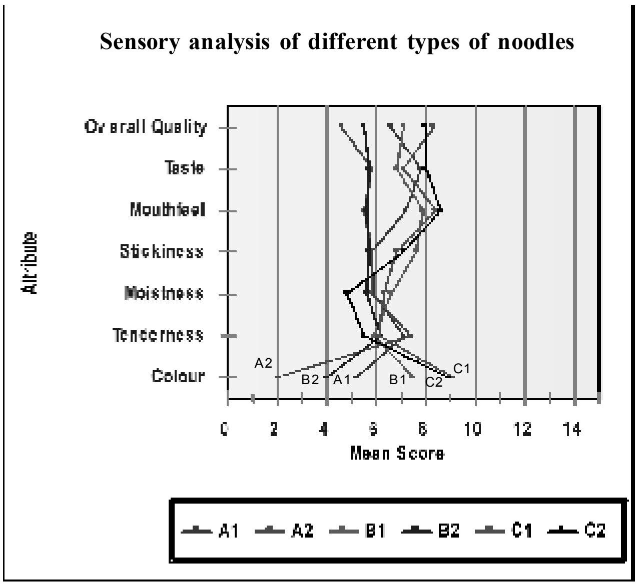
During cooking at 95°C for 20 minutes the viscosity decreased because of breaking of swollen starch granules and this was measured as Hot Paste Viscosity. The values for brown rice was 650, under milled rice 610 and 1170 BU for highly polished rice, respectively. Cold paste viscosity increased from brown rice to highly polished rice, and values were 1360, 1410 and 2000 BU respectively. Break down which is the difference between peak viscosity and hot paste viscosity was high in brown rice, and decreased from brown rice to highly polished rice.Set back which is the difference between cold paste viscosity and peak viscosity also increased from brown rice to highly polished rice which was due to the association of starch molecules in other words it was due to retrogradation of starch granules. The values for brown, under milled and, highly polished rice were 380, 500 and 670 BU, respectively.

Total set back (difference between cold paste viscosity and hot paste viscosity) which is an indication of total precipitation of linear molecules. The values were 710 for brown, 800 for under milled, and 830 BU for highly polished rice. Relative Break Down, which is the ratio of Break Down to Total Set Back, also decreased from brown rice to highly polished rice (0.375 to 0.192). The viscography parameters for different steamed samples have been shown in the Table 7. The gelatinization temperature was calculated with correction as informed before. The values were 80°C, 78°C, and 76°C for brown, under milled, and highly polished rice respectively.

However, the peak viscosity, hot paste viscosity, cold peak viscosity and break down values increased from steamed brown rice to steamed highly polished rice flour, indicating the pure involvement of starch granules. But the set back values remained same for steamed brown as well as steamed under milled rice, where as that of steamed highly polished rice decreased to 330 from 530 BU. Even total set back and relative break down values also increased from steamed brown rice to steamed highly polished rice. Viscosity of brown as well as under milled rice noodles were almost same (Table 8) but that of highly polished rice noodles reduced by about 60 cps. This may be due to the severe processing steps, where highly polished rice under goes higher degradation compared to under milled as well as brown rice, which are protected by the bran layer on the endosperm, which may be one of the reasons for showing higher value in the case of noodles from brown as well as under milled rice. In steamed brown rice noodles the value was high (~ 440 cps). This high viscosity may be due to the partial retrogradation which had taken place while steaming and drying of the paddy as well as the bran portion which had supported for the increase in viscosity. This was also observed by Jagtap *et al.* (2008), where viscosity was quite high in the case of parboiled rice. It reduced in steamed under milled rice noodles by about 100 cps, but again it was high in steamed highly polished rice noodles, which may be because of the retrogradation which had taken place while steaming and drying of the paddy.

Table 8. Viscosity measurement of different types of noodle by Brooke field instrument

Type of rice	Viscosity (cps)
Brown rice	355
Under milled rice	350
Highly polished rice	290
Steamed brown rice	439
Steamed under milled rice	344
Steamed high polished rice	392



A_1 - Steamed Brown Rice, A2 - Raw Brown Rice, B_1 - Steamed Under-milled Rice, B_2 - Raw Under-milled Rice, C2 - Steamed Highly Polished Rice

Fig. 1. Sensory analysis of different types of Noodles

Sensory evaluation was done by a group of nine panelists. They evaluated the noodles on the basis of different attributes like colour and appearance, tenderness, moistness, stickiness, mouth feel, taste and over all quality. Panelist did the evaluation on the basis of scorecard provided to them and gave ranking to the given samples. Different results were obtained through which a profilograph was made between the attributes and the mean scores (Fig. 1).

Both steamed highly polished and raw highly polished rice noodle samples were rated best for the over all quality. Raw highly polished and steamed brown rice noodle samples had better taste than raw brown and raw under milled rice noodle samples. Steamed highly polished and raw highly polished rice noodles gave a better mouth feel with steamed under-milled rice noodles closely followed it. The stickiness of steamed under-milled, raw highly polished and steamed highly polished rice samples were rated higher than steamed under-milled and raw brown rice noodles samples. There was not much significant difference in tenderness among the samples but raw brown and steamed brown rice noodle samples were the best in tenderness attribute. Steamed brown and raw brown rice noodle samples have same degree of moistness. There was much significant difference with respect to colour attribute with steamed highly polished and raw highly polished rice noodle being rated the best. Steamed brown rice noodles ranging intermediate between steamed under milled rice and raw brown rice noodle samples.

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