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*Corresponding authors: Waqas N. Baba and Sabeera Muzaffar, Department of Food Science and Technology, University of Kashmir, Srinagar, India
E-mails: waqasbaba7@gmail.com (Waqas N. Baba); sabeera_ku@gmail.com (Sabeera Muzaffar)

F.A. Masoodi is the mentor of the manuscript.

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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

A correlation study of proximate composition, physical and cooking properties of new high yielding and disease resistant rice varieties

Nuzhat Rasool¹, Waqas N. Baba^{1*}, Sabeera Muzaffar^{1*}, F.A. Masoodi¹, Mudasir Ahmad¹ and Mohd Munaff Bhat²

Abstract: The present study was aimed to compare proximate composition, physical, and cooking properties of locally cultivated rice varieties of Kashmir division viz.; SR-1, K-448, and K-39. Various physiochemical properties were studied. The relationship between physical, proximate composition, and cooking properties was determined using Pearson's correlation. Length–breadth (L/B) ratio showed a significant positive correlation with kernel length and negative correlation with thousand kernel weight, with a correlation coefficient (r) of 0.893 and -0.855 , respectively, ($p < 0.01$). Protein content was found to be negatively correlated with ash ($r = -0.489$, $p > 0.05$). Solid loss in gruel was observed to have a negative correlation with L/B ratio ($r = -0.432$, $p > 0.05$), water uptake ratio ($r = -0.742$, $p < 0.05$), and cooking time ($r = -0.678$, $p < 0.05$). The rice cultivars with higher cooking time showed lower gruel solid loss and vice versa. Water uptake was observed to be positively correlated with L/B ratio ($r = 0.768$, $p < 0.05$). Among all the cultivars studied, K-448 variety has potential for consumers' preference and it could be used for breeding programs for the improvement of valuable grain quality traits.

Subjects: Food Chemistry; Food Engineering; Food Science & Technology

Keywords: SR-1; K-448 and K-39; physical properties; proximate composition; cooking characteristics; correlation

ABOUT THE AUTHORS

Nuzhat Rasool is an independent researcher and has completed her master's in Food Science and Technology from the department of Food science and technology.

Waqas N. Baba is working as a lab assistant in Department of Food Science and Technology, University of Kashmir.

Sabeera Muzaffar is an assistant professor in the Department of Food Science and Technology, University of Kashmir.

F.A. Masoodi is a professor cum head of the Department of Food Science and Technology, University of Kashmir.

Mudasir Ahmad is a doctoral fellow in the Department of Food Science and Technology, University of Kashmir.

PUBLIC INTEREST STATEMENT

Rice is a staple food in major parts of the world. Kashmir Himalayan region due to its ecological fragility, climatic instability, and limited land resource has led to introduction of some new varieties of rice such as SR-1, K-448, and K-39 to ensure food security. These varieties have been established either for their high yielding or for disease resistant characteristics. This research focuses on the nutritional, physical, and cooking characteristics of these varieties. The paper will help in establishing technological and market superiority of these varieties and hence consumer preference. Technologically superior varieties of rice can be subjected to further breeding programs and special focus can be given for their cultivation in this region. Further correlation analysis has been done to evaluate influence of the studied parameters on each other.

1. Introduction

Rice (*Oryza sativa*) belongs to the family Gramineae that includes 20 wild and two cultivated species, viz. Asian rice (*O. sativa*) and African rice (*Oryza glaberrima*). *O. sativa* is the most commonly grown species throughout the world today (Oko & Ugwu, 2011). Rice (*O. sativa*) has been considered the best staple food for over three billion people, constituting over half of the world's population (Cantral & Reeves, 2002). Rice (*O. sativa*) has been adapted and consumed by humans for almost 5,000 years (Zhou, Robards, Helliwell, & Blanchard, 2002) and is ranked as world's number one human food crop (Itani, Tamaki, & Arai, 2002). At global level, rice occupies an area of about 153.77 m ha which is 30% of the total area under food grains. India occupies the highest area of 45 m ha under rice with a production of 91.0 metric tons next only to china accounting for 46% area under cereals and 42% of total grains (Anonymous, 2007). Rice production in India has witnessed a spectacular increase in the recent past and is approximately one-third of the total rice production of the world (Singh, Kaur, Singh Sodhi, & Singh Sekhon, 2005).

Rice (*O. sativa*) provides about 75% of the protein in the average daily diet of people (Anonymous, 2002). Over two billion people in Asia alone derive 80% of their energy needs from rice, which contains 80% carbohydrates, 7–8% protein, 3% fat, and 3% fiber (Juliano, 1985). Rice is the only cereal crop cooked and consumed mainly as whole grain, and quality considerations are much more important than for any other food crop (Sarowar Hossain, Kumar Singh, & uz-Zaman, 2009). Quality of rice may be considered from the viewpoint of size, shape, appearance of grain, and cooking properties (Dela cruz & Khush, 2000). Varietal properties such as grain size, shape, thousand kernel weight, and bulk density affect the grains quality (Yadav, Khatkar, & Yadav, 2007). Grain quality evaluation always helps the consumers to select better rice varieties. Preference for grain size and shape may vary from one group of consumer to another (Khush, Paule, & Delacruz, 1979). For instance, high-income group of people in Bangladesh prefer long slender grain, whereas, lower income group prefer bold grains (Anonymous, 1997). Cooking quality of rice is one of the important factors influencing the acceptability of consumers. During cooking, amylose leaches out of the starch granule and retrogrades or stales when cooled, whereas amylopectin remains in the gelatinized granule. Cooking quality preferences vary within the country, within ethnic groups, and from one country to another or within different geographical regions (Juliano, Bautista, Lugay, & Reyes, 1964). Genetic, handling, storage, and environmental factors are mainly responsible for the variation in composition and cooking quality of rice (Daniels, Marks, Siebenmorgen, Mcnew, & Meullenet, 1998; Faruq, Prophan, & Nezhadahmadi, 2015; Tsugita, Ohta, & Kato, 1983). The eating quality is determined by physicochemical properties such as water absorption, cooking quality, and gelatinization of starch (Chrastil, 1990, 1994; Kaur, Ranawanaa, & Henrya, 2015; Kong, Zhu, Sui, & Bao, 2015). Therefore, physicochemical and cooking quality determines the overall assessment of rice grain.

Himalayan regions (Kashmir area) of India are prone to change in land use due to geo-ecological fragility and it climatic instability. Keeping in view, several new varieties of rice (such as SR-1, K-448 and K-39) have been introduced that are disease resistant and high yielding. They are under cultivation and the net returns under survey offered by these cultivars have led to an increase in there cultivation as well as consumption (Mubarak, Bhat, Zargar, & Wani, 2013). Based on this fact, the objective of the present study was to compare physicochemical and cooking properties of locally cultivated rice varieties of Kashmir Division.

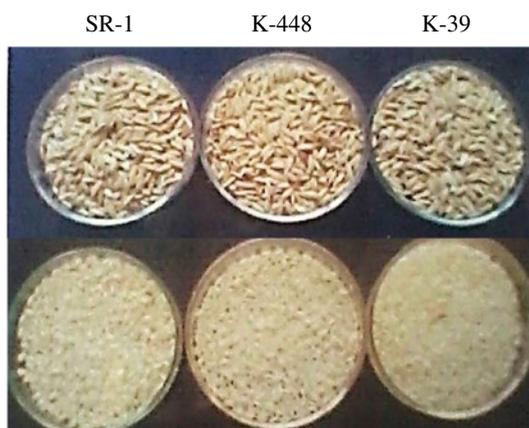
2. Material and methods

The investigation was done in the Department of Food Science and Technology, University of Kashmir. A total of three rice cultivars of Kashmir division (SR-1, K-448 and K-39) were selected for this research and were procured from Agriculture Department, Lal Mandi, from the 2014 harvest.

2.1. Preparation of sample

The paddy sample was dehulled and milled in one-step process in a laboratory-scale mill (barbender quarderent junior). Milled whole rice kernels were separated from broken rice for the evaluation of physicochemical and cooking properties (Figure 1).

Figure 1. Paddy and rice kernels of SR-1, K-448, K-39.



2.2. Physical properties of rice

Physical characteristics were measured as per method of Sarangapani, Devi, Thirundas, Annapure, and Deshmukh (2015). Length and breadth of raw rice kernels were reported as an average of 10 grains and repeated in triplicates. Measurements were done using Vernier caliper and the Ratio of length and breadth gave L/B ratio. One thousand head rice kernels were counted randomly in triplicates and weighed separately using Analytical balance (Sartorius, CPA 225D). Mean of three replications was recorded. One hundred head rice kernels of milled rice were counted randomly in triplicates and weighed using Analytical balance (Sartorius, CPA 225D). Mean of three replications was recorded. Bulk density was determined as described by Singh et al. (2005). Milled whole rice kernels from different rice cultivars were poured into a certain known volume in a measuring cylinder from a fixed height and the mass of the sample occupying the volume was determined. Ratio was calculated as g/ml.

2.3. Cooking properties of rice

Milled head rice was cooked for the minimum cooking time as described by Singh et al. (2005). Head rice (2 g) was taken in a test tube from each variety and cooked in 20 ml distilled water in a boiling water bath. The cooking time was determined by removing a few kernels at different time intervals during cooking and pressing between two glass plates until no white core was left. Water uptake ratio was determined as described by Dela cruz and Khush (2000). Cumulative length of cooked rice kernels was divided by length of uncooked raw kernels and the result was reported as elongation ratio (Soponronnarit, Chiawwet, Prachayawarakorn, Tungtrakul, & Taechapiroj, 2008). Five cooked grains were placed breadth-wise on a flat plane surface along a millimeter scale. Cumulative width of five cooked rice kernels was divided by width of five uncooked raw kernels and the result was reported as width ratio (Yadav et al., 2007). Cooked length-breadth (L/B) ratio was determined by divided the cumulative length of five cooked kernels by the breadth of five cooked kernels. A mean of three replications was reported (Singh et al., 2005). Solids in cooking gruel were determined by drying 10 ml of aliquot at 120°C to a constant weight. The solid were weighed and percent gruel solids were reported.

2.4. Proximate composition of rice

The kernels were ground to flour in a milling machine and all experiments were done in triplicates. Moisture content of rice flour was determined by digital infra-red moisture Analyzer (Sartorius MA 100) which was maintained at 100°C. Micro Kjeldahl method using Elite Ex, Kelplus automatic nitrogen analyzer of pelican equipment, Chennai, India was used to determine nitrogen content (AACC, 1987). The resulting N₂ content was multiplied by a factor 6.25 to convert into crude protein. Fat content was determined by Soxtec Apparatus (soxtec™ 2043-10011700/Rev.2). Petroleum ether was used as solvent. Ash content was determined according to the procedure of AOAC (1995).

2.5. Statistical analysis

All experiments were performed in triplicates and the mean values with standard errors were reported. The data were subjected to statistical analysis using one factor Analysis of variance (ANOVA) in a completely randomized design using Opstat. Pearson's correlation coefficient (r) was calculated using MINITAB 13 version statistical software.

3. Result and discussion

3.1. Physical properties of milled rice

The physical properties of milled rice are shown in (Table 1). Significant differences in the grain dimensions were noted ($p < 0.05$). The kernel length and breadth of the reported varieties varied from 5.60 to 5.86 mm and 2.36 to 2.53 mm. K-448 varieties showed the highest kernel length (5.86 mm), whereas K-39 had the smallest kernel length of (5.60 mm). The lowest kernel breadth was recorded in K-448 variety. Kernel breadth has been found to be negatively correlated with kernel length ($r = -0.778, p < 0.05$). The L/B ratio varied from 2.21 to 2.47. The highest L/B ratio was shown by K-448 variety (2.47). Cultivars having L/B ratio less than 3.0 are termed as medium grain varieties (FAO/WHO, 1995). Grain length positively correlates with L/B ratio ($r = 0.893, p < 0.01$). Thongbam et al. (2010) have also reported the positive correlation between grain length and L/B ratio. Significant variation in thousand kernel weight was seen in our study ($p < 0.05$). K-448 variety had the lowest thousand kernel weight (20.46 g) whereas, K-39 showed the highest value for thousand kernel weight (21.54 g). L/B ratio was negatively correlated with thousand kernel weight ($r = -0.855, p < 0.01$). Yadav, Kumar, Shivay, and Singh (2009) have also reported the negative correlation between thousand kernel weight and length–breadth (L/B) ratio. Hundred kernel weight varied from 2.01 to 2.15 g. Hundred kernel weight was positively correlated with thousand kernel weight ($r = 0.859, p < 0.01$). Significant difference in bulk density was reported ($p < 0.05$). The bulk density of various rice cultivars varied from 0.82 to 0.85 g/ml, (higher for coarse grains). Bhattacharya, Sowbhagya, and Swamy (1972) observed that bulk density is related to the kernel shape, i.e. L/B ratio, the more round the kernel, the greater the bulk density. Fan, Siebenmorgen, Gartman, and Gardisser (1998) reported that the medium grain cultivars showed higher bulk density for brown and white rice than did the long grain cultivars. Overall, the cultivars having larger grains showed lower bulk density. Bulk density was negatively correlated with cooking time ($r = -0.813, p < 0.01$). Yadav et al. (2007) have also reported a strong negative correlation between bulk density and cooking time.

3.2. Chemical properties of milled rice

Table 2 depicts the chemical properties of rice varieties. Moisture content of all the three rice varieties varied non-significantly ($p > 0.05$) from 12.18 to 12.63% that indicates similar agro-climatic conditions or the place where the paddy was stored. The protein content among the rice varieties varied from 6.13 to 8.33%. According to Juliano (1998), the protein content of milled rice is about 8.0 g/100 g even though varietal differences have been established. Our result agreed with this statement with the exception of K-448 variety that showed a slight higher protein content than other samples, which could be due to genetic make-up or wider plant spacing, where more nitrogen is available to plants. Protein content has been found to be negatively correlated with ash content ($r = -0.489, p > 0.05$). Thongbam et al. (2010) have reported similar correlation between the protein content with ash. In the present study, the fat content varied from 0.66 to 0.98%. The fat content of milled rice has been reported to vary from 0.2 to 2.0% (Zhou et al., 2002). The higher value found for the sample SR-1 could be due to the germ presence and residual outer layer of the kernel (Acquistucci, Francisci, Bucci, Ritota, & Mazzini, 2009). The ash content varied significantly among the varieties ($p < 0.05$) and its range was between 0.33(SR-1) and 0.97(K-39)%. The difference in ash content could be due to climatic conditions or environmental factors. Fat content was observed to have a highly significant and negative correlation with ash ($r = -0.899, p < 0.01$). Similar observations regarding the correlation of fat with ash content have been reported by Thongbam et al. (2010).

Table 1. Physical properties of milled rice from different rice cultivars

Cultivar	Length (mm)	Breadth (mm)	L/B ratio	TKW (g)	HKW (g)	BD (g/ml)
SR-1	5.633 ^a ± 0.033	2.533 ^a ± 0.067	2.223 ^a ± 0.073	21.280 ^a ± 0.005	2.053 ^a ± 0.003	0.843 ^a ± 0.003
K-448	5.867 ^b ± 0.033	2.367 ^b ± 0.033	2.473 ^b ± 0.023	20.463 ^b ± 0.004	2.013 ^b ± 0.003	0.823 ^b ± 0.003
K-39	5.600 ^a ± 0.001	2.533 ^a ± 0.033	2.210 ^c ± 0.030	21.540 ^c ± 0.000	2.153 ^c ± 0.003	0.850 ^c ± 0.000
CD	0.096	NS	0.168	0.014	0.012	0.010

Notes: Values are mean ± standard deviations of three (*n* = 3) replications with different superscripts in a column vary significantly (*p* ≤ 0.05).

TKW: Thousand kernel weight (g); HKW: Hundred kernel weight (g); CD: Cumulative difference; BD: Bulk density; NS: Not significant.

Table 2. Proximate composition of milled rice from different rice cultivars

Cultivar	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
SR-1	12.187 ^a ± 0.263	7.227 ^a ± 0.007	0.983 ^a ± 0.003	0.333 ^a ± 0.003
K-448	12.630 ^b ± 0.030	8.333 ^b ± 0.003	0.833 ^b ± 0.033	0.660 ^b ± 0.006
K-39	12.457 ^c ± 0.034	6.133 ^c ± 0.003	0.667 ^c ± 0.067	0.977 ^c ± 0.003
CD	NS	0.017	0.152	0.015

Notes: Values are mean ± standard deviations of three (*n* = 3) replications with different superscripts in a column vary significantly (*p* ≤ 0.05).

CD: Cumulative difference; NS: Not significant.

3.3. Cooking properties of milled rice

The cooking properties of various rice cultivars are presented in (Table 3). Water uptake ratio varied from 2.03 to 2.45 g/g. A maximum water uptake ratio of 2.45 g/g was recorded in K-448 variety. Water uptake ratio was positively correlated with L/B ratio (*r* = 0.768, *p* < 0.05) (Table 4). Bhattacharya and Sowbhagya (1971) and Yadav et al. (2007) have also reported a strong positive correlation between water uptake and L/B ratio. Elongation ratio ranged from 1.29 to 1.53. K-448 variety showed the highest elongation ratio, whereas K-39 had the least value, higher elongation ratio is preferred than lower elongation ratio for quality of cooked rice (Singh, Gautam, Sanjeev, & Singh, 2000). Elongation ratio had a positive correlation with L/B ratio (*r* = 0.514 *p* > 0.05) and water uptake (*r* = 0.930, *p* < 0.01). The results of this study are in accordance with those reported earlier by Khan and Ali (1985), Singh et al. (2005), and Yadav et al. (2007). It has been reported earlier that Basmati-type cultivars such as IET-15391, IET-16310, and IET-16313, having higher L/B ratios, showed greater elongation ratio, respectively. The width ratio ranged from 1.15 to 1.41. K-448 variety showed the least value of width ratio (1.15) that is considered a good quality as width-wise increase is not a desirable characteristic in high quality rice and urban people prefer the varieties that expand more in length than in breadth (Choudhary, 1979). Yadav et al. (2007) have reported similar results about

Table 3. Cooking properties of milled rice from different rice cultivars

Cultivar	WU ratio (g/g)	E ratio	Width ratio	Cooked L/B ratio	SL in gruel (%)	CT (min)
SR-1	2.247 ^a ± 0.003	1.467 ^a ± 0.033	1.413 ^a ± 0.003	2.660 ^a ± 0.000	1.533 ^a ± 0.088	25.000 ^a ± 0.289
K-448	2.453 ^b ± 0.003	1.533 ^b ± 0.003	1.150 ^b ± 0.000	2.683 ^b ± 0.003	1.333 ^b ± 0.088	22.000 ^b ± 0.289
K-39	2.033 ^c ± 0.033	1.290 ^c ± 0.000	1.383 ^c ± 0.003	2.467 ^c ± 0.003	1.667 ^c ± 0.120	27.000 ^c ± 0.289
CD	0.069	0.068	0.010	0.010	NS	1.018

Notes: Values are mean ± standard deviations of three (*n* = 3) replications with different superscripts in a column vary significantly (*p* ≤ 0.05).

WU: Water uptake; E: Elongation; SL: Solid loss; CT: Cooking time; CD: Cumulative difference; NS: Not significant.

Table 4. Pearson correlation coefficients between various physico-chemical and cooking properties of different rice cultivars

	L	B	L/B ratio	TKW	HKW	BD	Moisture	Protein	Fat	Ash	WU ratio	E ratio	W ratio	CLB ratio	S loss
Breadth	-0.778*														
L/B ratio	0.893**	-0.977**													
TKW	-0.942**	0.738*	-0.855**												
HKW	-0.739*	0.523	-0.633	0.859**											
BD	-0.819**	0.611	-0.729*	0.950**	0.838**										
Moisture	0.436	-0.406	0.443	-0.403	-0.095	-0.368									
Protein	0.874**	-0.660	0.776*	-0.959**	-0.967**	-0.911**	0.247								
Fat	0.143	-0.041	0.076	-0.235	-0.645	-0.190	-0.356	0.475							
Ash	-0.098	-0.003	-0.034	0.223	0.685*	0.221	0.384	-0.489	-0.899**						
WU ratio	0.857**	-0.659	0.768*	-0.943**	-0.961**	-0.896**	0.225	0.988**	0.540	-0.493					
E ratio	0.671*	-0.386	0.514	-0.828**	-0.974**	-0.839**	0.081	0.935**	0.640	-0.671*	0.930**				
W ratio	-0.923**	0.743*	-0.851**	0.943**	0.643	0.895**	0.550	-0.811**	0.075	-0.113	-0.790*	-0.619			
CLB ratio	0.642	-0.436	0.536	-0.754*	-0.979**	-0.713*	-0.017	0.909**	0.761*	-0.806**	0.905**	0.952**	-0.494		
S loss	-0.498	0.341	-0.432	0.688	0.685*	0.713*	-0.122	-0.694*	-0.414	0.271	-0.742*	-0.717*	0.606	-0.612	
C Time	0.829**	-0.678*	0.770*	-0.900**	-0.961**	-0.813**	0.134	0.975**	0.604	-0.575	0.978**	0.916**	-0.718*	0.936**	-0.678*

Notes: Values are mean ± standard deviations of three (n = 3) replications with different superscripts in a column vary significantly (p ≤ 0.05).
 L: Length; W: Width; BD: Bulk density; WU: Water uptake; E: Elongation; CLB: Cooked length breadth; S loss: Solid loss in gruel; TKW: Thousand kernel weight; HKW: Hundred Kernel weight; BD: Bulk density;
 WU: Water uptake; CT: Cooking time; CD: Cumulative difference.
 *p < 0.05.
 **p < 0.01.

width ratio. The cooked (L/B) ratio of the rice varieties varied from 2.46 to 2.68. The L/B ratio of cooked rice was highest for K-448 variety, which indicates good cooking quality. The data also revealed a negative correlation of cooked length–breadth (L/b) ratio with width ratio ($r = -0.494$, $p > 0.05$). Solids released by rice into cooking water have also been considered as a cooking quality attribute (Juliano, 1985). The data recorded for solid loss in gruel varied from 1.33 to 1.66%. K-39 showed the highest gruel solid loss of 1.66% and K-448 variety showed the lowest value of 1.33%. The high elongation ratio and low solid loss in K-448 variety may be due to greater strength of cell wall line that is able to hold the pressure until maximum elongation takes place without rupturing of cell wall (Chandi & Sogi, 2008). Solid loss had a significant negative correlation with L/B ratio ($r = -0.432$, $p > 0.05$), water uptake ratio ($r = -0.742$, $p < 0.05$), and cooking time ($r = -0.678$, $p < 0.05$) (Table 1). Similar observation regarding the correlation of solid loss in gruel with L/B ratio, water uptake ratio, and cooking time has been reported by Vaingankar and Kulkarni (1986), Singh et al. (2005), and Yadav et al. (2007). In the present study, cooking time of milled rice varied from 22 to 27 min. A maximum cooking time of 27 min was recorded for K-448 variety and the least for K-39. The difference in cooking time among the cultivars may be due to differences in amylose content. The rice with higher amylose content has been reported to have higher gelatinization temperature (Juliano, 1985). Cooking time was found to have a highly significant and positive correlation with water uptake ($r = 0.978$, $p < 0.01$). Similar observation regarding the correlation of cooking time with water uptake ratio has been reported by Yadav et al. (2007). Overall, the difference in cooking properties between rice varieties may be due to genetic make-up and difference in their granular structure.

4. Conclusion

Based on established results, it was concluded that appearance of milled rice could be used as indicator for predicting their elongation ratio and cooked L/B ratio, because the rice with greater length and L/B ratio showed greater elongation and cooked L/B ratio. Cultivar K-448 showed high protein content (8.33%) among all the three varieties studied. Thus, revealing its superior nutrient quality, K-448 variety also showed good cooking characteristics i.e. high elongation ratio, water uptake ratio, cooked length–breadth (L/B) ratio, and a low width ratio cooking time and solid loss in gruel. Thus, K-448 variety has potential for consumer preference and could be used for breeding programs for the improvement of valuable grain quality traits.

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Competing interests

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Author details

Nuzhat Rasool¹
E-mail: nuz2009@gmail.com
Waqas N. Baba¹
E-mail: waqasbaba7@gmail.com
Sabeera Muzzaffar¹
E-mail: sabeera_ku@gmail.com
F.A. Masoodi¹
E-mail: masoodi_fa@yahoo.co.in
Mudasir Ahmad¹
E-mail: mudasirahmad63@yahoo.in
Mohd Munaff Bhat²
E-mail: ffanum@gmail.com

¹ Department of Food Science and Technology, University of Kashmir, Srinagar, India.

² Sheri-Kashmir Institute of Agricultural University of Science and Technology, Shalimar, Srinagar, India.

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