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# Changing priorities in rice grain and nutritional quality research

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## ABSTRACT

*Having achieved self-sufficiency in production, the rice (Oryza sativa) improvement programs now focus on sustaining the gains and enhancing the grain and nutritional quality of rice. Rice farming is labour intensive and is generally not considered remunerative. This calls for the efforts to breed rice varieties not only with higher productivity but also with superior grain quality fit for mass consumption as well as for industrial production of breakfast cereals and other rice based products. A sound understanding of the factors that contribute to the overall grain quality of rice will lay the foundation for developing new breeding and selection strategies for combining quality with high yield. With availability of some molecular markers and the information on genes controlling rice quality traits, breeding strategies now focus on improving rice grain quality by exploiting such genes. Traditionally, characteristics like right shape (medium and long slender rice grains), translucent endosperm, good milling quality, high head rice recovery, excellent cooking /eating quality, good elongation and pleasant aroma were considered important for a variety to qualify as quality rice. Besides these, thin husk, high nutrient density, least nutrient losses during milling /washing and lesser cooking time are also considered desirable traits. Of late, high nutrient density (with emphasis on increased iron, zinc, protein, provitaminA carotenoids in grain), low phytate, low glycemic index, high antioxidant value and therapeutic value and suitability to develop consumer products are also being pursued as quality/speciality traits for rice. The older and the newer traits defining quality and the present day methods that are used to assess quality are briefly discussed.*

***Key words:*** *Rice, grain, nutritional quality, starch, glycemic index*

## INTRODUCTION

Rice, the second most consumed cereal forms an integral part of the diet of about half of the global population. It comprises two species namely, *Oryza sativa* and *Oryza glaberrima*, which are native to tropical and subtropical Asia and Africa, respectively. Rice is basically a self-pollinated crop. It is one of the most versatile crops as it grows in diverse ecologies under a variety of water regimes- ranging from mountain tops to upland areas and irrigated plain fields to semi-deep water and deep water areas of all continents except the Antarctica, the earth's coldest and driest continent. Rice farming is labour intensive and despite the large global rice area under cultivation, rice farming is generally not considered remunerative. This calls for the efforts to breed rice varieties not only with higher productivity but also with superior grain quality fit for mass consumption as well as for industrial production of breakfast cereals and other rice based products.

With rising living standards, rice grain quality improvement has become priority area for research as it is directly related to market price and has the potential to raise rice farmers' income on which the government is giving high emphasis. For this, rice farming needs to meet multiple objectives with utilization of each and every part of rice plant. The farmer adopts varieties that give high yield and have good grain quality traits. The development of such rice varieties is a challenging task, especially in view of the dwindling natural resources and global climate change.

Among cereals, rice has the smallest genome (430 million nucleotide pairs distributed over 12 pairs of chromosomes) which has been completely sequenced (Tyagi, et al 2004). Many studies have shown that rice quality is mainly controlled by genes (Tan et al., 1999; Mikami, 2000; Tran et al., 2011). Hence, breeders should now focus on improving grain quality of rice (including hybrid rice which gives high yield but is often poor in grain quality) (Lu et al. 2001; Min et al. 2007; Zhao, 2008) by manipulating genes that control various quality traits. Molecular markers based techniques are increasingly used in advanced rice chemistry laboratories to classify grain quality of rice to improve the overall quality including eating, cooking, and nutritional quality of rice. But only a few molecular markers have been associated with functionally validated rice grain quality traits so far. These molecular markers have found limited use to explain variations in rice amylose composition, amylopectin fine structure and scent(Vito et al, 2019).

## Rice grain quality

Quality in general refers to the degree of excellence or worth or grade of something. Grain quality characteristics assume much more importance for rice compared to other food grains and are the prime determinants of market price because almost 95% of the rice is consumed as cooked whole grain. The paddy arrives at the rice mill first where it is milled (the husk and the bran layer are removed together with the germ).Some of the grains are broken during milling; the brokens sale at considerably low price compared to the intact grains. Thus a variety with good milling quality is one that withstands the pressure of milling and polishing and yet yields high amount of total rice grains (milling yield) and a good amount of 'intact' grains (head rice).The consumer selects rice on the basis of its appearance, size, shape and also on its cooking and eating quality i.e. whether the cooked grains are soft or tough, well separate or sticky, aromatic or not, and finally, how they taste.

Rice quality traits comprise milling and head rice recovery, physical appearance, cooking and eating characteristics, and nutritional value (Juliano, 1972, 1985; Cheng et al., 2005).Though preferences for cooking and eating quality differ from region to region, the requirements for milling recovery, head rice recovery, grain appearance and low chalk are almost universal (Fitzgerald et al., 2009).

Stickiness of cooked rice grain is an important quality trait. It may not be a desirable trait in countries like India and Bangladesh where people normally like well separated cooked grains, but in some countries like Japan, sticky rice is preferred because it suits their habit of eating with chop sticks. Thus, notion of rice grain quality varies with the consumer. The concept of quality of the manufacturer of processed products is based on the suitability of the rice for the same. This requires rice varieties with different amylose content. Thus, suitability for intended end use is another aspect of rice grain quality which is important from the point of view of the manufacturers of such processed products. Thus, in summary, it is the consumer who defines grain quality.

The role of a rice grain quality analyst is to translate the consumer preference for quality into measurable physico-chemical parameters. Therefore, we need to develop new varieties for the characteristics liked by the consumer. We also need to develop newer and more accurate methods to evaluate the same in the laboratory to define consumer's choice in terms of specific physic-chemical parameters. As rice is a staple food for a large number of people, particularly those with limited income, who cannot afford other nutritious foods, its nutritional value is also important while considering the overall quality of a rice variety.

## Features of quality rice and quality traits that presently attract attention

Traditionally, characteristics like right shape (medium and long slender rice grains), translucent endosperm, good milling quality, high head rice recovery, excellent cooking/eating quality, good elongation and pleasant aroma were considered important for a variety to qualify as quality rice. Besides these, thin husk, high nutrient density, least nutrient losses during milling/ washing and lesser cooking time have also become desirable quality traits.

In addition, high nutrient density, low phytate, low glycemic index, high antioxidant value and therapeutic value are also being pursued as quality/

speciality traits. We shall discuss the older and the newer traits and mention the present day methods that are used to assess quality.

## Factors affecting rice grain quality

Rice grain quality traits are variety specific characters which are influenced by cultural practices (how crop is grown), production environment (under what conditions it is grown) and also the post-harvest practices (how the harvested grains are processed and stored). Harvesting before maturity means a low milling recovery and also a higher proportion of immature seeds, high percentage of broken rice, poor grain quality and more chances of disease attack during storage of grain. Wet grains should be dried immediately after harvest, preferably within 24 hours to avoid heat accumulation. Delay in harvesting results in grain shattering and cracking of rice in the husk and exposes the crop to insects, rodents, birds and pests attack, as well as lodging. The lower quality of locally produced rice available in the market is due to the combined effects of the types of varieties grown, poor post-harvest management, and processing practices (Futakuchi et al., 2013 ).

## Cooking and eating quality of rice grains

### Cooking quality

A desirable cooking quality trait important from the point of commerce is that cooked grain should retain a firm shape and not disintegrate during or after cooking. As starch forms the major part of rice kernel, the cooking quality is mainly governed by the packaging of starch molecules (amylose and amylopectin) and their ratio. High amylose rice cook dry, separate and less tender and become hard on cooling, while low amylose rice become moist, soft and sticky on cooking. Water absorption and volume expansion during cooking are directly affected by amylose content. Waxy rice expands the least during cooking and is least resistant to disintegration, whereas the high amylose rice is most resistant to disintegration. The intermediate amylose rice are generally preferred the world over except where the waxy or low amylose rice are the choice.

The cooking quality is measured in terms of apparent amylose content (AAC%), alkali spreading value (ASV), gelatinization temperature (GT), water uptake (WU) value, volume expansion ratio (VER), kernel length after cooking (KLAC), elongation ratio (ER) and starch index (for basmati rice only). A Rapid Visco-Analyzer (RVA) is used to predict the cooking quality rather quickly. When rice flour is cooked, it turns into a thick paste with gradual increase in viscosity. The viscosity curves made by the RVA indicate the time taken and the temperature at which the transformation from raw flour to a cooked paste takes place. It also describes the behaviour of the paste as it cools.

## Apparent amylose content (AAC)

Amylose content of rice is considered to be one of the most important factors influencing the cooking eating and processing characteristics of rice. Low amylose levels are associated with cohesive, tender, and glossy cooked rice grains. Conversely, high levels of amylose cause rice to absorb more water and consequently expand more during cooking, and the grains tend to cook dry, fluffy, and separate (Juliano, 1971).

The blue colour obtained by the iodine binding to gelatinized rice flour is contributed by both-the linear chains of amylose molecule and the longer unbranched stretches of the amylopectin molecule. This is why we use the term 'apparent amylose content' (AAC) rather than amylose content (Takeda et al., 1987).Milled rice grains are classified as waxy (0-2%), very low (3-9%), low (10-19%), intermediate (20-25%), and high (>25%) amylose types based on the AAC (Kumar and Khush, 1986). Some researchers recommended the use of calibrated rice standards and measuring the blue colour at longer wavelengths (720 nm) to minimize the interference caused by the iodine-amylopectin complex (Fitzgerald et al., 2009).Others proposed to replace the acetate buffer (pH 4.5) with ammonium buffer (pH 9.0) to achieve the same objective and to obtain AAC values similar to the differential scanning calorimetry (DSC) method (Juliano et al., 2012). These values were as much as 3% lower than those obtained with acetate buffer. If this method is agreed to by rice scientists, the amylose based rice classification and breeding objectives shall need to be reset. AAC determination in ground milled rice using near-infrared (NIR) reflectance spectroscopy developed by Delwiche et al. (1995) yielded values closer to the colorimetric method.

## Gel consistency (GC)

Gel consistency (GC) values determine whether or not the rice grains will remain soft after cooking (Juliano, 1979). Normally, the GC of rice with up to 24% amylose is soft. Rice with soft GC cook tender and remain soft even upon cooling and hence are preferred by consumers. Such rice are a priority for breeding programme. The consumers in South- East Asia prefer rice grains with softer GC. Hence most rice breeding programs in the region aim at breeding soft GC rice (Khush et al.,1979). In this test, which was originally developed to exclusively distinguish between textural attributes of high amylose rice grains with 24-30% AAC (Cagampang et al., 1973),we measure the horizontal migration of cold rice paste after cooking and cooling using 13 × 100 mm glass test tubes and rice is said to be of hard (27-40 mm), medium (41-60 mm), and soft (61-100 mm) GC depending on the migration of rice paste. Hard GC is due to high content of long-chain amylopectin, while soft GC is because of a higher proportion of short-chain amylopectin. Hard gel consistency correlates with a high content of long-chain amylopectin with high iodine affinity, found in high-AC rice (Takeda et al., 1987; Horibata et al., 2004). Our experience at the ICAR-NRRI, Cuttack regarding the GC method has been that it needs modifications so as to get precise and reproducible values.

## Gelatinization temperature (GT) and alkali spreading value (ASV)

Gelatinization temperature (GT) of rice is the temperature at which there is irreversible swelling of starch granules due to absorption of water molecules accompanied by loss of crystallinity when rice is cooked. Rice starch usually gelatinises between 65°C and 85°C. At this temperature a rapid change from dispersion to paste is observed when the starch slurry is heated. Rice with high GT requires more water as well as time to cook compared to intermediate GT rice. It is, therefore, a good indicator of the time required to cook rice. The GT varies from 55-790C for various rice. It is traditionally measured by determining the loss of birefringence of starch granules as viewed under a polarized light microscope. Depending on value of GT, rice is classified as low GT (<$70^0$C), intermediate (70-$74^0$C) and high (>$74^0$C) GT rice (Juliano, 2007). GT is high for high amylose rice but then low amylose rice have also been found to have high GT. The waxy or low amylose rice have more free sugars and malto-dextrins which render them sweet. Low amylose rice do not have intermediate GT but intermediate GT rice are known to have intermediate or high amylose. The latter are normally preferred by people. Bhattacharya (2011) has referred to the various methods to measure GT in rice based on the changes in optical, hydration, swelling, crystallinity and viscosity parameters of flour slurry during cooking but the two methods based on grain digestion by alkali and DSC are normally used. These days, DSC is used for accurate measurement of GT but it is prohibitive due to the cost involved. High GT rice (>$74^0$C) take more water and time to cook becoming excessively soft when finally cooked; they disintegrate when overcooked and thus are not desirable. Growing of rice under high temperature conditions may result in increased GT values.

## Alkali spreading value (ASV)

GT is inversely related to the alkali spreading value (ASV). In fact, it is the ASV which is normally measured to have an idea of the GT. When rice is treated with dilute alkali (Little et al., 1958), the starch molecules present in rice swell resulting in disintegration of the grain. Depending upon the variety, the changes in the grain shape may vary from no apparent effect to a completely dispersed grain. The changes are recorded using a seven point scale on the basis of which the GT range of the rice may be ascertained. The waxy and the low amylose rice grains disintegrate fast whereas the high amylose grains retain the shape. Rapid Visco Analyzer (RVA) is a good machine due to the small (4g) sample size requirement, speed and ease of handling for GT determination. The AACC International has approved an RVA method (AACCI Method 61-04.01) to precisely estimate the GT of milled rice flour. It is more accurate in comparison to amylograph and the DSC methods (Dang and Bason, 2014).

## Water uptake (WU) value

WU values determined below boiling water temperature (70-$80^0$C) do not correspond to actual water absorption during cooking (Halick and Kelly, 1959). WU differentiates rice based on GT of starch. The lower the GT of the variety, the higher will be its water uptake. This method has also not been found to be satisfactorily reproducible as per our experience.

## Eating quality

The eating quality describes how the cooked grain feels in the mouth (hard or tender, sticky or fluffy and its scent). The criteria for eating quality (palatability) evaluation used to grade table rice consist of six sensory tests, which include appearance, aroma, taste, stickiness, hardness and overall evaluation. The eating quality is assessed by a 10-15 member panel that gives the description of cooked rice by using a seven point scoring scale system. We need more objective tests to define eating quality.

## Hybrid rice quality issues

The cooking and eating quality of rice grains is a challenging problem in many rice producing areas of the world. Most of the hybrid rice released in India had the cms line IR58025 A as the female parent, which itself had slight unpleasant aroma together with relatively low amylose content. Thus, the resulting hybrids also inherited these characteristics to some extent. But, the CRRI scientists used new cms lines to develop its hybrids Rajlaxmi and Ajaya, which are, therefore, free from these undesirable characteristics. The grain to grain variation in hybrid rice quality observed for some of the traits like amylose content, which is also reflected in alkali spreading value, can be overcome by selecting parents with similar amylose content. Amylose content (AC), gel consistency (GC) and gelatinization temperature (GT) are the most important constituents of the cooking and eating quality of rice grains.

Molecular marker-based genetic analysis in the last decade established that each of the quality traits is mainly conditioned by a major locus. For example, the Wx locus on chromosome 6 plays major roles in specifying AAC and GC plus a minor role in GT and the *Alk* locus, tightly linked to *Wx*, has a major effect on GT. For appearance quality traits, grain length is mostly controlled by the *GS3* locus on chromosome 3, and grain width is largely conditioned by *GS5* on chromosome 5. A major locus for chalkiness (*Chk5*) was also identified on chromosome 5. Several genes for these traits have been cloned. The single-locus inheritance clearly indicated that MAS can play a major role in quality improvement. Indeed, Zhou et al. (2003) were able to simultaneously improve the quality of Zhenshan 97, the female parent of a number of widely used hybrids in China with poor quality because of a high AAC, low GC, and a low GT, together with a chalky endosperm. MAS was applied to introgress the Wx gene region from Minghui 63 that has medium AAC, soft GC, and high GT to Zhenshan 97, then from Zhenshan 97B to Zhenshan 97A. The selected lines and their hybrids with Minghui 63, or Shanyou 63 (wx-MH) showed a reduced AAC and an increased GC and GT, coupled with reduced grain chalkiness, representing a significant improvement in cooking, eating, and appearance quality. Some studies have suggested that, in order to obtain desirable grain quality in hybrid rice, it is necessary to reduce chalky rice rate and chalky area and increase gel consistency.

## Nutritional quality: Increased emphasis on characterizing nutrient dense rice

Brown rice contains about 90% starch, 7% protein and 2% fat on dry weight basis. Though rice is a major source of calories and nutrients for millions of people, it is not a nutrient dense crop. Lack of diversity in daily diet due to poor economic condition of people makes them depend almost solely on rice for nutrition. This often results in iron, zinc, and vitamin A deficiencies among the poor in rice-consuming countries. Hence, improving the nutritional composition of rice grain by fortification or by screening for promising germplasm and using the best genotypes in breeding for improved nutritional value is another priority in rice quality research. A World Health Organization guideline (WHO, 2018) showed that fortification of rice to reduce malnutrition may involve different micronutrient strategies, including iron only, iron with zinc, vitamin A, and folic acid, or iron with other B-complex vitamins, such as thiamine, niacin, vitamin B6, and pantothenic acid.

Generally, rice contains about 7% protein but many varieties and land races contain even higher amounts. Protein is determined by Kjeldahl method to determine nitrogen content, which is converted to protein by the factor 5.95. [The factor, based on a nitrogen content of 16.8% for the major protein of milled rice (glutelin), may be an overestimation; reappraisals have suggested values of 5.1 to 5.66} (source: Rice in Human Nutrition - Page 44 - Google Books Result https://books.google.co.in/books?isbn=9251031495.]

The lysine content of rice protein is 3.5 -4.0%, one of the highest among cereal proteins. The net protein utilization of rice protein is 75% (Juliano, 2003). Earlier, an inverse relationship was observed between grain protein content and yield of rice varieties (Penning, et al., 1974). The ICAR-NRRI conducted research on improving rice grain protein content without compromising grain yield and has released CR Dhan 310 (NRRI, 2017) and CR Dhan 311 that contain 10.2% protein; the latter also contains 21 ppm zinc. A new advanced line of rice, with higher yield, with a protein content of 10.6% (a 53% increase from its original protein content) is ready for release, which needs less heat, time, and usually less water to cook (source: American Society of Agronomy. "High-protein rice brings value, nutrition: Science Daily,23 January 2019. www.sciencedaily.com/releases/2019/01/190123105809.htm).

Rice bran -the part which is removed after polishing, is rich in micronutrients. Enhancing their content in the endosperm is a challenge. Biofortifying rice with pro-vitaminA carotenoids, iron, zinc and protein are now routine activities in rice quality research. Though high zinc and high protein rice are available, limited success has been achieved in biofortifying rice with iron through breeding (Kok et al., 2018). The development of iron-rich rice will go a long way to reduce the iron deficiency induced anaemia and hence the overall health and productivity of the rice consuming countries.

Zinc is essential for survival, and its deficiency has serious consequences for health, particularly for the children when zinc requirements are the highest. The Bangladesh Rice Research Institute (BRRI) released in 2013 (source: Rice Today, Vol. 12 No. 4) the world's first zinc-rich rice variety, BRRI Dhan 62, containing 20 - 22 ppm of zinc. Some other high-zinc rice varieties developed through conventional breeding are also available in the country.

The development of golden rice(each gram of golden rice 2 contains up to 37 micrograms of the pro vitamin A carotenoids) is considered a bright example of genetic engineering to address vitamin A deficiency in people especially the rice eaters. Though it could not be not released (as it is a genetically engineered food crop and 'feared' to cause health problems) for mass consumption, attempts to transfer the high provitaminA trait to Asian rice varieties continues (Anonymous, 2008).

## Low glycemic index (GI) rice

Glycemic index is a ranking system for carbohydrate rich foods based on their immediate effect on blood glucose levels after consumption. Rice is generally considered to be a high GI food. Long-term consumption is often linked to an increased risk of developing Type II diabetes which has adverse effect on health, if untreated. The ICAR- NRRI, Cuttack has recently emerged as a centre for research on GI of rice. It has screened more than 100 rice varieties by GI using in vitro method and has shown that the GI of rice genotypes varies widely. They also work on the effect of mixed diet involving rice on GI value. One of the important conclusions drawn by them is that rice varieties with higher resistant starch content invariably have comparatively low GI values (Kumar, 2018). The rice Shaktiman with GI of 57 and Nuadhusura with still lower values have been identified (personal communication).

## Characterizing low phytate rice

*Myo*-inositol 1,2,3,4,5,6-hexakisphosphate (InsP6), or phytic acid (PA) is the principal storage form of phosphorus (P) in cereal grains which accounts for about 65%-85% of the total seed P (Raboy, 2000); the remaining P being in the form of soluble inorganic phosphate and that associated with nucleic acids, proteins, lipids and sugars (Larson et al., 2000). PA is negatively charged and hence strongly chelates cations like calcium, magnesium, potassium, iron and zinc. It usually exists as mixed salts referred to as phytate or phytin (Raboy, 2003). Thus, PA lowers the absorption and bioavailability of important nutrients in the human intestine resulting in micronutrient deficiencies. Phytase hydrolyses PA to lower inositol phosphates like inositol pentaphosphate (InsP5), inositol tetraphosphate, inositol triphosphate, inositol diphosphate and inositol monophosphate, during grain storage, fermentation, germination, food processing and digestion in the human gut (Burbano et al., 1995; Azeke et al., 2011; Hayakawa et al., 2014). However, only InsP6 and InsP5 have a major inhibitory effect on mineral bioavailability (Sandberg et al. 1999). About 90% of the phosphorus in bran is present as phytin; mainly as potassium and magnesium salts.

The ICAR-NRRI, Cuttack have screened hundreds of rice germplasm and varieties for PA and identified several low PA varieties (Kumar et al., 2017). Bindli is one of them. It is a very promising rice with several other useful traits (personal communication).

## Challenge of grain quality under climate change

Rice genotypes differ widely in quality. The growing environment has profound effect on grain appearance, milling, and eating quality (Ashida et al., 2013; Li et al., 2018). Among grain quality traits, head rice recovery and chalkiness are most significantly affected by environment (Zhao & Fitzgerald, 2013). In view of the changing environment, there is renewed interest in identifying and developing climate smart varieties that have acceptable grain appearance (low or no chalkiness) and high head rice recovery percentage.

The poor grain quality of indica rice limits its use in cooking. Temperature and atmospheric $CO_2$ concentration are important factors that impact rice grain quality. Due to global climatic change, atmospheric $CO_2$ concentrations have increased together with global temperatures (NOAA, 2013). Studies have shown that high $CO_2$ concentrations and temperatures can worsen milling recovery and physical appearance (Madan et al., 2012; Usui et al., 2014). Rice grown experimentally under elevated carbon dioxide levels, similar to those predicted for the year 2100, had less iron, zinc, and protein, as well as lower levels of thiamin, riboflavin, folic acid, and pantothenic acid (Wishart & Skye, 2018). Hence, in near future the research on improving rice yield and quality shall have to be focussed on adapting rice to the adverse effect of increased $CO_2$ concentrations and temperatures.

## Recent trends in developing newer and better rice grain quality tests

An excellent account of newer rice quality tests being developed and used has been given by Vito et al. (2019). Most of these tests involve the use of non-destructive, multi-parameter assays that correlate well with currently used methods. They give precise data with high throughput techniques, though they are expensive. The authors have listed spectroscopic techniques such as NIRS, Fourier transform infrared spectroscopy (FTIR), and Raman spectroscopy show promising potential in characterizing the cooking quality of rice grains. Several spectroscopic techniques, mostly using NIRS, were employed to characterize apparent amylose, moisture, protein, and fat contents, gelatinization, pasting, and textural properties as well as solid loss, volumetric expansion, and water uptake of rice during cooking.

To characterize the several levels of organization of starch structure combining flow field-flow fractionation (FFF) with multi-angle laser light scattering (MALLS) and differential refractometer index (DRI) have been successfully used in fractionating starch in aqueous conditions (Roger et al., 2001). Rolland-Sabaté et al. (2011) describe two separation methods using asymmetrical flow field flow fractionation (A4F) and hydrodynamic and size-exclusion chromatography (HDC-SEC) to determine the molecular size and mass distributions of native starches including rice.

The free solution capillary electrophoresis (CE) is expected to provide a better alternative to the conventional de-branched SEC technique as it determines native starch structure, composition, and degree of branching (Mantovani et al., 2018). Spectroscopic techniques such as NIRS, Fourier transform infrared spectroscopy (FTIR) and Raman spectroscopy show promising potential in characterizing the cooking quality of rice grains.

Predictive model associating textural properties of rice with the physicochemical parameters of rice grains have also been done in the past. One such model revealed that AAC, blue value (BV), and moisture content (MC) significantly influence the texture of rice (Zhu et al., 2010). The use of electronic nose (e-nose) and electronic tongue (e-tongue) to detect volatile and non-volatile compounds in food and beverages is now becoming popular (Baldwin et al., 2011).The main challenge for sensory profiling of rice grain is to identify instrumental methods that are well correlated with sensory traits has been addressed to some extent (Sesmat and Meullenet, 2001).

## CONCLUSION

Rice grain quality comprises traits that include appearance quality, milling quality, biochemical composition, cooking, eating, nutritional, and sensory properties. It is mainly decided by consumer preference which vary a lot from region to region the world over. Starch makes up the major part of rice kernel and is thus a prime determinant of rice grain quality. The cooking quality is described by apparent amylose content, gelatinization temperature, and gel consistency. Some of the procedures traditionally used to evaluate grain quality parameters such as GC, WU and AAC need to be reviewed/improved for reproducibility.

More recent techniques being used to define rice grain quality and consumer preference have been briefly described from available literature. The crossing of parental lines known to possess desirable grain qualities with high yielding lines is the first step toward enhancing both traits through breeding. In indica rice, new germplasm resources need to be identified and the introgression of relevant gene/s from *japonica* may improve the quality traits. Development of climate smart high yielding rice including hybrid rice with superior grain quality is the need of the hour. Development of nutrient dense rice, low GI rice and low phytate rice is in progress, which is likely to enhance rice farmers' income.

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