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Nutrient rich quality rice- a journey to healthy life

Abstract

Malnutrition continues to be a crucial problem particularly in developing countries. For this, rice breeding needs to be re-oriented to improve cooking quality, glycemic load, protein, amino acid, micronutrient, vitamin, phenolic and flavonoid content while increasing the yield potential. Indeed, the task is challenging as most of the traits relating to quality and nutrient status in rice are complex. In this pursuit, the authors reviewed the general background of malnutrition; explore the genetic basis for improvement of nutritional status including quality aspects and possible breeding perspective to mitigate the problem. This would certainly help breeders to develop nutritionally rich rice varieties.

Keywords: *oryza sativa*, nutrient rich, quality rice, breeding perspective

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Introduction

Rice *(Oryza sativa)* is the staple food for almost two-thirds of the population and it plays a pivotal role in Indian economy. Rice accounts 43% of total food production and 55% of cereal production in the country. India has largest area of rice cultivation (44mill. ha) and continues to rank second in rice production. Self-sufficiency in rice production and continued upliftment in economic condition have resulted changing life styles and increased awareness among consumers to improve and diversify diets including quality of rice consumed. The global rice consumption is estimated to be 54kg/capita/year. China and India together account for more than half of the global rice consumption.[1] Almost 31% of calories of Indian diet are estimated to be supplied through rice.

Half of the world's population is suffering from one or more vitamin and/or mineral deficiency[2] and increasing the risk of illness and premature death. More than three billion people are affected by micronutrient malnutrition and 3.1million children die each year out of mal nutrition[3] and the numbers are gradually increasing.[4] The situation is more alarming in developing countries than their advanced counterpart. Nutritional value of rice is being improved by biofortification approaches in developing countries. Vitamins and minerals are now being coated on rice kernels to supplement the requirement for healthy diet. A recent meet at Bangkok (Thailand) under the aegis of the United Nations Children's Fund (UNICEF) and the World Food Programme (WFP), look at opportunities to expand the production and distribution of the nutrient-rich grain (fortified rice) by using new technologies for adding vitamins and minerals to rice grain. But, it is costly and may not be affordable to larger section of the people in developing countries. Alternatively, sprouted brown rice can be used as it is nutritious owing to enhancement of important nutrients (bio-available forms of protein and fiber, vitamins e.g., B6, B12 and E and also lysine and magnesium) along with many health supporting benefits including improved digestibility and neutralization of phytic acid (an anti-nutritional component) in germinating seed.

In Asia and Africa, it is estimated that 500 to 600million people are at risk for low zinc intake. Health problems caused by zinc deficiency include anorexia, dwarfism, weak immune system, skin lesions, hypogonadism and diarrhea. Males aged 15 to 74years need about 12 to 15mg of zinc daily while females aged 12 to 74years need about 68 mg of zinc daily. Globally more than 3billion people were affected by Fe deficiency. Iron dependent anemia in turn leads to maternal mortality, preterm births, decreases immunity and increases placental weight during pregnancy. Further, the iron requirement is highest during 7-9months of pregnancy. About 85% of rice consumption is mainly white rice. Consumption of white sticky rices (polished rice) stimulates adverse metabolic affect and increases their glycemic load or impact on blood sugar levels. Patients suffering from diabetes fail to secrete required amount of insulin making them more vulnerable to the dreadful diabetic problems. Besides, these tend to have the risk of acquired blindness, renal failure, colon cancer and cardiovascular diseases. In this context, brown rice and wild rice are most preferred healthier food stuff[5] as they contain more nutrients and fiber. But, the lasting solution lies with breeding of high yielding nutrient rich quality rice to fight hunger and malnutrition among the common poor in developing countries. In this review, the authors attempted to reflect various dimentions of the cause of malnutrition and possible options to mitigate the same as a journey to healthy life

Quality rice

Cooking quality

Basmati rice is a resident of India by birth. Indian basmati– the soft cooking aromatic rice is acclaimed as the best quality rice in the world market due to its unique features e.g., pleasant and subtle aroma, delicate taste, extra long super fine grain, extreme elongation upon cooking (more than double the original length), intermediate amylose content and high head rice recovery. India is the largest producer and exporter of basmati rice in the world. Brown basmati rice has the lowest glycemic load and contains many minerals and vitamins; and therefore, it is often considered a healthy choice. Genetic mechanism for quality traits in rice is much complex and there is always a need of a balance among different quality traits for a rice variety to be fit for table purpose. In rice, eight main-effect QTLs including two for amylase content (AC), three for gelatinization temperature (GT), two for gel consistency (GC) and one for protein content have been identified using a BIL (backcross inbred line) mapping population derived from the cross between Koshihikari (good eating and cooking quality, japonica) and Kasalath (poor quality, indica).[6] However, Sabouri et al.,[7] identified twelve independent QTLs using composite interval mapping. These loci consisted of three QTLs for GT, eight QTLs for AC and one QTL for GC.

Glycemic Index(GI)

It is a highly complex trait. Rice varieties possessing slowly digestible starch (high amylose) are potentially characterized to have low glycemic index and can be useful for management of type II diabetes. Understanding genetic mechanisms underlying starch biosynthesis and metabolism of cooked rice can pave the way for developing efficient breeding and selection strategy for combining high grain yield with low glycemic index. In this context, reverse genetics can prove useful. Available rice genome sequence information encoding key enzymes involved in biosynthesis of amylase component of starch can unravel novel alleles involving single nucleotide polymorphisms (SNPs). A multi-allelic waxy gene (Wx) encoding Granule-Bound Starch Synthase I (GBSS I) enzyme is known to determine amylase content in rice endosperm. GI of rice is shown to have negative relationship with amylose content. In fact, at least 18 highly polymorphic starch biosynthesis related genes contribute directly or indirectly to the GI by altering the amylose and amylopectin content in rice.[8] More than 2000 varieties of rice are now cultivated around the globe[9] and these vary in GI (48-92%) owing to varying levels of amylose content.[10] Indian Institute of Rice Research, Hyderabad has identified four rice varieties e.g. Lalat, BPT 5204, IR 66 and Sampada with low GI values (<55). Some Australian, Indonesian, Indian and Bangladeshi varieties have been reported to have lower GI than other rices. Notable among these are the amylose heavy basmati type rices and the mega rice variety "Swarna" showing low GI, while IR 65 is a waxy variety which contains no amylose (highest GI). In Philippines, a brown rice variant called Sinandomeng was categorised as low GI (55.0), while its milled version had the GI value as high as 75.0.[11] Ferulic acid, a predominant phenolic acid found in rice[12] is reported to reduce blood glucose by enhancing gluco kinase activity, promoting glycogenesis and stimulating plasma insulin secretions in diabetic rats.[13]

Nutrient rich rice

Our present day rice varieties are poor in protein content and mostly deficient in variety of nutrients. There is an urgent need to explore available genetic resources for nutrient dense rice genotypes and unravel the genetic mechanism underlying expression of nutritional traits.

Protein content

Rice contributes about 40% of the protein intake through diet in developing countries. Protein content in milled rice is about 7-8% in brown rice, while it may go up to 16% as in brown rice of ARC 10063 and ARC 10075.[14] Seed protein content in rice is controlled by 49 genes.[15] Limited success has been achieved so far towards development of protein rich rice. This is mainly due to the complex inheritance pattern and appreciably large environmental effect on protein content. Tan et al.,[16] mapped a major QTL close to the waxy gene (Wx) on chromosome 6 and another on chromosome 7. Recently, protein content in brown and milled rice has been mapped to chromosome 8, 9 and 10.[17] Using ARC 10075 as a donor, NRRI, Cuttack has developed a rice variety "CR Dhan 310" with high protein content (11%) and rich in threonine and lysine.

Amino acids

Rice is relatively deficient in lysine and tryptophan. There was a dearth need to alter amino acid composition in seed storage proteins. Altering amino acid composition is not easy by conventional breeding technique. In this context, use of SNP markers can unravel variation in amino acid composition. Wang et al.,[18] detected QTLs for all essential amino acids except tryptophan, glutamine, and asparagines in rice grain. Most QTLs were shown to be co-localized and three major QTL clusters are reported to be located on chromosome 1, 7 and 9 respectively.[19] Among these, the QTL cluster on Chromosome 9 *(qAa 9)* is related to increased lysine content.

Minerals and vitamins

Minerals play beneficial role in human metabolism. Rice grain is relatively low in some essential micronutrients such as iron (Fe), zinc (Zn) and calcium (Ca) as compared to other crops.[20] Rice varieties vary in mineral content.[21] Brown rice is an important source of vitamins and minerals. Modern high yielding rice varieties are deficient in Fe and Zn. Zn serves as cofactor for more than 300 enzymes and it also act as the coordinating ion in the DNA-binding domains of transcription factors. M. S. Swaminathan Research Foundation (MSSRF) identified nine nutritionally rich landraces from the tribal districts of Odisha and Kerala. Concentration of zinc and iron in these rice varieties is almost three times more than that of the conventional varieties. Proper screening methodology is an urgent need as variability of soil types may definitely interfere with screening of such rices. Wild rice *(O. rufipogon)* retains favourable alleles for most of the 26 QTLs identified for Fe -content in rice grain and 14 such QTLs on chromosome 1, 9 and 12 accounts 45% of phenotypic variation.[22] Norton et al.,[23] reported ten QTLs for five mineral elements (Cu, Ca, Zn, Mn and Fe) and Fe *(qFe-1)*. Lu et al.[24] observed 10 QTLs for Ca, Fe, Mn, and Zn accumulation in rice grains on seven chromosomes. Gande et al.,[25] identified an important candidate gene *(OsZIP8a)* responsible for Zn content in rice seed which explained 19% of phenotypic variation.

Phenolics and flavonoids

Phenolics e.g., tocopherol, tocotrienols and γ-oryzanol available in red rice serve as antioxidants. Thus, pigmented rice often termed as medicinal rice, can reduce oxidative stress and even prevent the risk of cardiac arrest and certain cancers. Red and black kernel rice contain flavonoids e.g., proanthocyanin and anthocyanin respectively. In addition, red rice harbours higher proportion of gallic acid. While, black/purple rice is reported to have higher amount of Fe, Zn, Ca, Cu and Mg than red rice.[26] Yafang et al.[27] and Shao et al.,[28] identified two molecular markers (RM339 and RM316) commonly used for study of genetic variation in a set of rice genotypes for antioxidant, flavonoids and phenolic content. Phosphorous pools transported to rice grain is reserved in form of phytate which also serve as antioxidant and has major role in seedling vigour upon germination of seed. James et al.,[29] identified two QTLs for phytate concentration on chromosome 5 and 12.

Breeding perspective

With the increasing demand and consumers' preference, rice breeding programme needs to focus on development of nutrient dense quality rice for value addition and thereby to eradicate malnutrition. High yielding nutrient dense cultivars can be bred by selective breeding or through genetic modification.[3] Genes and QTLs are recently known for the nutritional quality of rice. Genomics can dominate such endeavour in order to develop more efficient nutritional rich rice cultivars.[30] Allele mining can be useful to unravel the allelic variation in genes underlying the traits. Besides, advanced genomic technologies such as SNPs array, genome sequencing, genome-wide association mapping, transcriptome profiling, etc. could be strategically exploited to understand molecular mechanism and their relation between the genotypes and phenotypic traits leading to development of improved rice varieties.[31] Compatible QTLs/genes erstwhile mentioned may be combined together to design a desirable genotype with superior in multiple grain quality traits.[32] This can be achieved by introgression of nutrition related QTLs/genes to improve the efficiency of classical plant breeding via marker-assisted selection (MAS). Besides, transgenic assisted breeding approaches with classical breeding may be a way forward for success.

A few fixed breeding lines with relatively rich in iron (>10ppm) and zinc(>20ppm) in kernels (after 10% polishing) have been identified by IIRR, Hyderabad and those are now introduced in the breeding programme as donors. Bangladesh Rice Research Institute (BRRI) released (in 2013) the world's first zinc-enriched early maturing rice variety "BRRI Dhan-62" capable to fight diarrhea and pneumonia-induced childhood deaths and stunting. Besides, a rice variety "Chattisgarh Zinc rice 1"- rich in protein(10%) and zinc(30ppm) has been released by Indira Gandhi Krishi Vishwavidyalaya(IGKV), Raipur which seems to be a boon for malnourished populations in tribal districts of Chhattisgarh. It is the first zinc fortified rice variety developed by India. Thus, genotypes can be bred for increased uptake and utilization of trace minerals (eg, zinc and iron) and these may be amenable for simultaneous improvement of crop productivity and human nutrition.[33] Many workers tried to transfer and express biofortification genes in rice grain. Three-fold increase in Fe- content was achieved in transgenic rice using soybean ferritin gene.[34] Zheng et al.,[35] observed 5-fold iron accumulation in polished rice grain owing to over expression of endosperm specific NAS *(Nicotinamide Synthase)* gene *of Hordeum vulgare* in rice. Rice lacks the ability to produce *β-carotene,* the precursor of Vitamin A. Ye et al.,[36] developed golden rice that yields 1.6-2.0μg/g of β-carotene of dry rice resulting recovery from night blindness. This was possible by introgression of four major genes conditioning *photogene synthase, phytoene desaturase, β-carotene desaturase*, and *lycopene β-cyclase*into rice.

Conclusion

Quality and nutritional traits are in fact more complex in nature. A delicate balance among these traits is not clearly understood. In recent years, identification of genes/QTLs underlying these traits are still in progress. Genomic strategies combined with traditional breeding are expected to create new horizon to achieve towards nutritional security.

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Conflict of interest

The author declares no conflict of interest.

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