SPECIALTY RICE VARIETIES AND LANDRACES

S.S.Karkee[1]

ABSTRACTS

Rice is a staple food for half of the world's population and is the major source of calories for the people of rice-growing countries. Nowadays, nutritionists are more concerned about hidden hunger as people with sufficient food intake may be deprived of important nutrients that may be absent in the food they consume. Similarly, white rice (polished rice) that only contains endosperm is lacking several essential nutrients like Fe, Zn, fiber, and antioxidant compounds, etc. To increase the nutritive content of these rice and minimize the problem of hidden hunger, different rice varieties are being tested with artificial addition of nutrients, such varieties are called biofortified rice. Special rice like black, purple, brown rice, contain natural antioxidant compounds in their outer bran layer, aromatic rice is rice in aroma, glutinous rice is popular for their sticky and sweet test. At the same time these special rice are also rich in several micronutrients. In addition to nutrition content, people's taste preferences are also considered a major concern. This review paper focused on specialty rice varieties and landraces along with their unique values.

Keywords: Aromatic rice, Biofortified rice, Pigmented rice, Starchy rice

INTRODUCTION

Rice is staple food and more than 2 billion people obtain 60-70% of the daily calorie intake from rice in Asia only. The grains of rice are being consumed in its milled form or white rice by approximately half of the population of the world (Puri *et.al,* 2014). People preferences towards white rice due to easy cooking, palatability, longer storage and fancy appearance (Upadhyay and Karn, 2018). Before consumption these rice under goes processing steps like hulling and polishing results removal of outer layers of husk, bran, and embryo i.e., only the endosperm region is left (Roy *et al.,* 2011) in contrast. This layer of rice is important as it contains various important elements and compounds like Fe, Zn, thiamine, niacin, Flavonoids, melatonin, phenolic, vitamins, minerals, etc. that are essential for human health.

There are several landrace cultivars of rice which are naturally rich in nutrients and qualities like aroma, taste, etc. that might be absent in modern rice cultivars (Berni *et al.*, 2018). More than 276 secondary metabolites from rice have been identified that mainly include phenolic acids, flavonoids, terpenoids, steroids, alkaloids, and their derivatives. These metabolites exhibit various kinds of biological activities such as antimicrobial, antioxidant, cytotoxic, and anti-inflammatory properties (Wang *et al.,* 2018).

1 Agriculture and Forestry University, Email:surazkarkee23@gmail.com

In recent year attraction towards these rice landraces is growing due to their quality content and health benefits as their consumption has been linked to lowering the risk of diseases related to oxidative stress i.e. inhibitory effects on carcinogenesis and

Mutagenesis (Setyaningsih *et al.,* 2015). These are non-other than pigmented rice, glutinous rice, long grain rice, and scented/aromatic rice. These rice cultivars have been growing form centuries and have nutritional, cultural, and medicinal importance. The products from these cultivars have also become more widely appreciated in the current global market.

White rice (polished rice) lacks several micronutrients that cause a serious problem like hidden hunger in rice eating countries due to unbalance diet intake (Maclean *et al.,* 2002). Though landrace cultivars had potential to solve hidden hunger but their low productivity they are not preferred by farmers (Mau *et al.,* 2017). To address this nutrient demand and food demand agriculture and food scientists are focusing on increasing the production of nutritive rice that contains essential nutrients in their endosperm and are high yielding. For this they are adopting technologies as biofortification that involves enriching the modern high yielding rice with nutrients like Fe, Zn, Vitamin A, etc. Similarly, food scientists are also focused on adding antioxidant compounds in transgenic rice and antioxidant-rich rice plants have been successfully generated viz. purple rice (Zhu, 2017).

Table 1. Effect of processing on nutrient content of rice (Abbas *et al.,* 2011).

S.N.	Extraction Rate %	100 Rough	82 Brown rice	72 Milling rice
	Mineral content			
1.	Calcium (mg/g)	0.3	0.1	0.1
2.	Phosphorus (mg/g)	3.1	3.2	1.5
3.	Zinc (ppm)	2.4	3.3	18.0
4.	Iron (ppm)	38.0	8.8	4.1
5.	Copper (ppm)	2.8	2.7	2.2
	Vitamin Content			
6.	Thiamine (µg/g)	2.8	2.4	1.6
7.	Riboflavin (µg/g)	0.5	0.3	0.2
8.	Niacin (µg/g)	29.6	29.0	6.0
9.	Pyridoxine (µg/g)	5.1	5.1	1.9
10.	Biotin (µg/g)	91.0	48.0	43.0

OBJECTIVES

The objective of this paper is to review about different specialty rice cultivars including landraces that were handed by our ancestors and modern nutritive rice developed by adopting different breeding techniques. In addition, it also includes unique feature that makes these cultivars different from others.

METHODS AND MATERIALS

A number of research and reviewed articles related to White or polished rice, specialty rice cultivars and landrace have been reviewed to prepare this paper. Basically, Google Scholars, Google book, and Research gate, are main search engine to extract related articles.

CLASSIFICATION OF SPECIALTY RICE CULTIVARS (VARIETIES AND LANDRACES)

The classification is based on their special feature and the specialty content is natural or artificially induced through different breeding techniques.

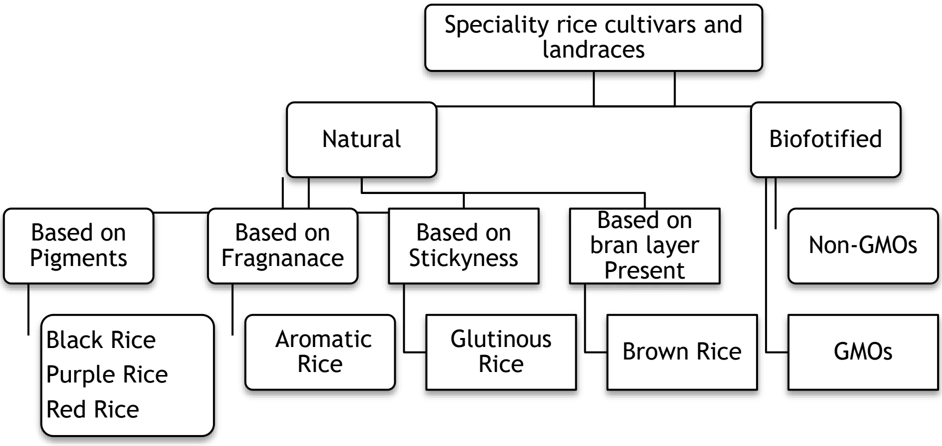

Fig 1: Classification of Special Rice cultivars and landraces on different basis

Table 2: Different specialty rice landraces and varieties with their examples (Joshi, 2017; Majumder *et. al.*, 2019)

S.N.	Basis	Special Rice cultivar	Speciality	Examples
1.	Based on color	Black rice	Pigment on bran layer	Kalo dhan
		Purple rice		
		Red rice		Wild rice
2.	Based on waxyness	Glutinous rice	Stickness	Anadi, Jumli marshi, Taichung-176, Chiure, Karange
3.	Based on fragrance	Aromatic rice		Kalomuniya, Jethobudho, Basmati Lalka Basmati, Motisar, Sali Dhan, Anadi Basnadhar Pahenle, Sunalo Sugandha

4.	Based on milling	Brown rice	Consists of bran layer	Dehusked rice (rice obtained from dhikki)
		White rice	Absent of bran layer	Milled (rice absent of bran and embryo layer)
5.	Based on fotification	Zn-Biofortifed rice	Higher Zn content	BRRI Dhan-62
		Fe-Biofortified rice	Higher Fe content	IR68144 rice
		VitA-Biofortified rice	High Vitamin A content	Golden rice

AROMATIC RICE

Aromatic or scented rice is a special group of rice recognized for their fragrance. Aroma or fragrance is one of the major qualities preferred among different other rice qualities like taste, color, nutrient, etc. Because of their aroma, flavor, and texture, aromatic varieties get a higher price in the market than do the non-aromatic rice varieties (Singh *et al.,* 2000).

Aromatic rice is native of the Indian subcontinent. Cultivation of aromatic rice is traditionally practices in the foothills of Himalayas in the Indian states of Uttar Pradesh (UP) and Bihar, and Terai region of Nepal (Singh *et al.,* 2000). The aromatic rice is mainly grown and consumed in India, Nepal, Pakistan, Thailand, Bangladesh, Afghanistan, Indonesia, Iran, and United States. Among these countries India, Pakistan, and Thailand export fine grain aromatic rice mostly to the Middle East, Europe, and USA with the annual export worth millions of dollars (Singh, 2000). It is estimated that there are over 300 aromatic rice varieties that are recognized, although the utilization and production of these varieties are limited. The popular aromatic rice of the world are Basmati rice of India, Nepal and Pakistan, Dulhabhog of Bangladesh, Khalo Dawk Mali and Leuang Hawn of Thailand, Azucena and Milfor of the Philippines, Rojolele of Indonesia, Sadri varieties of Iran, Barah of Afganistan, and Della of United States (Singh *et al.,* 2000)

The fragrance of aromatic rice is due to the presence of volatile compounds. There is no individual compound which imparts a pleasant odor to raw or cooked aromatic rice. Probably it is a blend of various volatiles and more than 114 compounds were recognized which imparts pleasant odor in aromatic rice. Among all these volatile compounds, 2-acetyl-1-pyrroline (2AP) is recognized as an important compound contributing to the aromatic odor (Buttery *et al.,* 1982). The pleasant aroma from aromatic rice is not only associated with cooked rice, some varieties emit aroma in the field from the flowering time. They release aroma from leaves, grains, and other parts. Chewing of immature grains is one of the popular methods for the rapid identification of aromatic rice varieties. Mittal *et al.*, (1995) reveled that aroma can be determined form leaves of a crop.

PIGMENTED RICE

Pigmented rice is those varieties and landraces in which the outer bran and aleurone layer contain the accumulated different pigmented substances. Pigments are phenolic compounds that give rice grain natural color ranging from brown to red (proanthocyanidins) or from purple to black (anthocyanins) (Deng *et al.,* 2013). It is reported that a wide range of phenolic compounds including anthocyanins, proanthocyanidins, 4-hydroxycinnamic acid, 4,7-dihydroxyvanilliv acid, syringaldehyde, vanillin, the group of p-coumaric, ferulic, sinapinic acids, etc. are found in pigmented rice (Deng *et al.*, 2013). Low molecular weight phenolic are found in grains with light brown pericarp color whereas grains with red and black pericarp color contain higher molecular weight phenolics (Goffman and Bergman, 2004).

Several researches reported the health benefit of pigmented rice and its bran phytochemicals that include anti-inflammatory, antioxidant, anticancer, and anti-aging activities etc. Phenolic compounds like tocopherol and anthocyanin extracted from pigmented rice are efficient neutralizers of reactive oxygen species (Krishnanunni *et al.,* 2014). Anti-diabetes activity inhibits the activity endogenous α-amylose and α-glucosidase, thereby inhibiting the conversion of starch to glucose in the small intestine which acts as a source of resistant starch to be utilized by gut microbiota in the colon (Boue *et al.,* 2016). A bioactive compound from pigmented rice acts as an anti-cancer by reducing the viability of cancer cells, anti-mutagens, blocking the carcinogenetic cytochromes (Baek *et al.,* 2015; Insuan *et al.,* 2017). Depending upon the pigment present, pigmented (colored) rice are classified as red rice, purple rice, and black rice (Limtrakul *et al.,* 2019).

1.1. Black rice

These are pigmented rice with pericarp or kernel deep purple or black in color (Karkee *et al.*, 2019). The color of this rice is due to the accumulation of anthocyanin in a different layer of the pericarp, seed coat, and aleuronic region (Chaudhary, 2003). The origin of black rice takes place in tropical Japonica and genes attributing blackness subsequent spread to the indica subspecies (Kushwaha, 2016). This rice has a long and glorious history as it is recognized as forbidden rice, heaven rice, imperial rice, king's rice, and prized rice since the high-class family was only allowed to consume the rice. The rice worked as a treasure as it protects from aging, had nutritional importance and used in ancient medicines.

There are more than 200 types of black rice varieties globally. Only China is responsible for 62 % of the global production of black rice and it has developed more than 54 modern black rice varieties with high yield characteristics and multiple disease resistances (Kushwaha, 2016). These rice cultivars are assumed as a panacea of many culinary diseases because of its high nutritive value and curative effect. This rice is supposed to enhance the longevity of life; hence it is also known as long life rice (Bolea *et al.,* 2019). The outer pericarp or aleuronic layer of rice contains pigments like proanthocyanin, and anthocyanin. These compounds have several health benefits like antioxidant properties. Anthocyanin helps to minimize the toxic effect of free radicles (Khoo *et al.,* 2017). Despite of antioxidant property the rice contains nutrients like Fe, Zn, Cu, Fiber, and several other beneficial nutrients which are lacking in normal rice. Daily consumption of this rice protects people from the disease like diabetes, obesity, cancer, and constipation etc.

1.2. Purple rice

Purple rice is pigmented glutinous rice with characteristic purple pigment in the pericarp and husk. Pigmentation of the grain in pericarp and husk is due to deposition of huge amount of the anthocyanin, phenolic acids, and flavonoids. Concentrated amount of these compounds in different layer of grain makes rice purple to black in color (Pusadee, *et al.,* 2019). This glutinous rice is native to Thailand. In Thailand, purple rice is called "BKao Kum" or "BKao Niaw Dam" where "Kum" means purple, "Dam" means black, "Kao" means rice, and "Neow" means glutinous grain type. This rice is culturally important germplasm in Asia with a long history of cultivation in China, India and Thailand (Kong *et al.,* 2008). It is grown in China, Japan, Korea, Sri Lanka, India, Bangladesh, Thailand, Laos, Philippines, and Indonesia (Sukhonthara *et al.,* 2009).

1.3. Red rice

These are weedy rice with red colored bran layer. These are termed as weed as they appear voluntarily in rice field. Red rice is colored rice with red colored bran layer. The coloration of bran is due to proanthocyanidin pigments (Wirjahardja *et al.,* 1983). These includes polyphenols and anthocyanin, and possesses antioxidant properties. The red rice are a richer source of protein, zinc and iron than white rice (FAO, 2004). It is usually eaten unhulled or partially hulled. Rice has a nutty flavor. Compared to polished rice, it has the highest nutritional value (Table 3). The importance of this rice is mentioned in Hindu religious books Agni, Vishnu and Garuda Purana as it delays thirsty, arrests perspiration and highly restorative. In different part of India rice is consumed to cure blood pressure and fever, intake by women during lactation, used for treating leucorrhea and abortion complication, preferred for coolness and a tonic (Saxena, 2014). The red rice yeast (prepared by fermenting yeast *Monascus purpurea* over red rice) is a popular cholesterol-lowering product over the world (Chaudhary and Tran, 2001).

Red rice can be found in different agro ecology as weeds of rice. These rice shows intermediate characteristics between wild and cultivated rice (Chen, 2001). Despite of nutrient rich the rice has great potential value as it can adapt extreme natural and versatile environment conditions and can be used as genetic material for developing new varieties in future. (Nadir, *et al.,* 2017).

Table 3: Nutrient content of red rice and white polished rice

S.N.	Parameters	White Rice	Red Rice
1.	Nutritional Parameters		
2.	Mositure content (g/100 gram)	12.75±0.15	12.7±0.13
3.	Crude Fat content (g/100 gram)	0.62±0.015	1.81±0.011
4.	Crude Fibre content (g/100 gram)	0.23±0.02	2.71±0.1
5.	Crude protein content (g/100 gram)	7.6±0.23	10.49±0.43
6.	Total Ash content (g/100 gram)	0.46±0.04	1.53±0.01
7.	Carbohydrate content (kcal/100 gram)	78.34±1.5	70.19±1.0
8.	Energy content (kcal/100 gram)	349.34±2.5	341±1.2
	Minerals and Antioxident properties		
9.	Calcium content (mg/100 gram)	7.94±0.17	8.71±0.65
10.	Iron content (mg/100 gram)	7.65±0.22	13.45±0.60
11.	Magnesium content (mg/100 gram)	46.45±0.649	192.27±5.98
12.	Zinc content (mg/100 gram)	1.49±0.039	1.91±0.036
13.	Total flavonoids content(mg/100 gm of flavonoids)	166.23±0.25	120.0 ±0.38
14.	Total phenolic content (mg GAE/100g of phenol)	24.26±1.05	143.38 ±1.5

(Source: Raghuvanshi, *et al.* 2017)

1.4. Brown

Brown rice is either un-hulled or partially hulled type of rice. It is whole grain rice which means the bran layer remains intact with grain after removal of the outer hull (Hasen *et al.,* 2012). This rice is different from usual white rice due to the presence of bran layer (Priya *et al.,* 2019). During the milling process, first of all the husk from the whole rice grain or paddy is removed to obtain the whole brown rice grain that contains the outer bran layer with commonly brown or reddish-brown color. After removal of the outer bran layer, the polished or white rice is obtained (Janet *et al.,* 2002). The bran layer consists of pericarp, aleurone, sub-aleurone layer, and germ which contain large amounts of nutrients and bioactive compounds (Table 4 and 5) and are known to have various beneficial properties (Juliano, 1993; Janet *et al.,* 2002).

The characteristics reddish brown or dark brown color of the bran layer of brown rice is due to the deposition of pigments like proanthocyanidins, vitamins, fibers, and minerals. (Pengkumsri, *et al.,* 2015). It can be consumed as an alternative to white rice as white rice has a high glycemic index and may result in high oxidative stress and other health risks (Saleh *et al.,* 2019). Recently studies have shown that white rice increases the risk of type 2 diabetes. Consumption of brown rice lowers insulin and glycemic indices and may confer other health benefits (Setyaningsih *et al.,* 2015). Similarly, consumption of germinating brown rice may improve texture, palatability, and the amount of the bioactive molecules. Patil& Khan (2011) reported that germinated brown rice have glucose and cholesterol lowering properties. Consumption of this brown rice product instead of white rice would provide enormous benefits since it will not have the same health risks as white rice but rather will promote health and reduce disease burden.

Table 4: Nutritional profile of different rice varieties in per 100 g serving

S.N.	Parameters	Black rice	Brown rice	Red rice	White rice
1.	Carbohydrate (g)	34 ± 0.05	24 ± 0.07	23 ± 0.04	28 ± 0.03
2.	Protein (g)	8.5 ± 0.5	7.9 ± 0.07	7 ± 0.05	2.7 ± 0.04
3.	Fat (g)	2 ± 0.06	0.8 ± 0.02 1	0.8 ± 0.01	4 0.3 ± 0.01
4.	Tocopherol (mg)	12.54 ± 0.34	2.2 ± 0.76	10.77 ± 0.24	0.1 ± 0.14
5.	Thiamin (B1) (mg)	0.46 ± 0.032	0.54 ± 0.07	0.33 ± 0.15	0.7 ± 0.06
6.	Riboflavin (B2) (mg)	0.403 ± 0.04	0.1 ± 0.2	0.105 ± 0.03	0.03 ± 0.33

(Source: Kumar and Murali, 2020)

Table 5: Nutrient contents of rice varieties

Type of Rice	Protein (g/100g)	Iron (mg/100g)	Zinc (mg/100g)	Fiber (g/100g)
White(policed) rice	6.8	1.2	0.5	0.6
Brown rice	7.9	2.2	0.5	2.8
Red rice	7.0	5.5	3.3	2.0
Purple rice	8.3	3.9	2.2	1.4
Black rice	8.5	3.5	--	4.9

Source: Food and Nutrition Division, FAO (2004)

1. Glutinous rice

Glutinous rice (*Oryza sativa var. glutinosa)* has sticky characteristics when cooked. Due to stickiness, the rice is also named as sticky or waxy rice. They may be both pigmented/non pigmented. After cooking, the rice gives a sweet taste and also called sweet rice (Noomhorm *et al.,* 1997). Lao People's Democratic Republic (Lao PDR) has been recognized as a center for glutinous rice biodiversity. About 2,470 germplasm or about one-fifth of the world germplasm was found in Loas PDR (Bestari, 2006). China is the largest in both production and consumption of glutinous rice. Glutinous rice shares about 3% of the world's milled rice production (USDA, 2018).

The waxy or stickiness in rice cultivar is characterized chiefly by a lack of amylose in the starch (Bean *et al.*, 1984). Natural starch contains two polymers; amylose (10-30%) and amylopectin (70-90%) (Taghvaei *et al.,* 2010)). Non-glutinous rice contains both molecules that makeup starch: amylopectin and amylose (Panesar and Kaur, 2016). Glutinous differs from the regular (non-glutinous) rice mainly in having low (<5%) or almost no amylose in its starch but basically high in amylopectin (Setyaningsih *et al.,* 2015). Amylose is essentially long chains composed of (1-4)-linked α-D-glycopyranosyl units with few (1-6)- α-linkages branches while as amylopectin has a higher molecular weight and much shorter chains of (1-4)-linked α-D-glucose units that are highly branched through additional (1-6)- α-linkages branches (Bertoft, 2017).In general, the amylose content of rice starch varies from (0-2%), very low (3-9%), low (10-19%), intermediate (20-25%) and high (>25%) (Kumar and Khush, 1986).It has been reported that many native varieties of glutinous rice have high nutrient content such as vitamin E, antioxidant, protein, beta carotene, and folate (Ratcha and Kongkachiuchai, 2013). Despite of health importance, it has been used in preparing many kinds of Asian traditional desserts and used in making rice wine, sushi, rice balls, and cakes

3. Bio-fortified rice

According to the WHO, is the process of nutritionally enhancing food crops through agronomic practices such as managing crops to promote soil and water conservation, conventional plant breeding and modern biotechnology, which can include GMO. Biofortification is similar with fortification as both of them increase the nutritional quality of the food. The major difference between them is that bio-fortification focuses on improving the nutritional content of the food during plant growth while fortification is done manually during processing of the crops. It refers to increasing genetically the bio-available mineral content of food crops by increasing the concentration of nutrients, promoter compounds, and a decrease in anti-nutrient substances (Brinch-Pederson *et al.,* 2007).

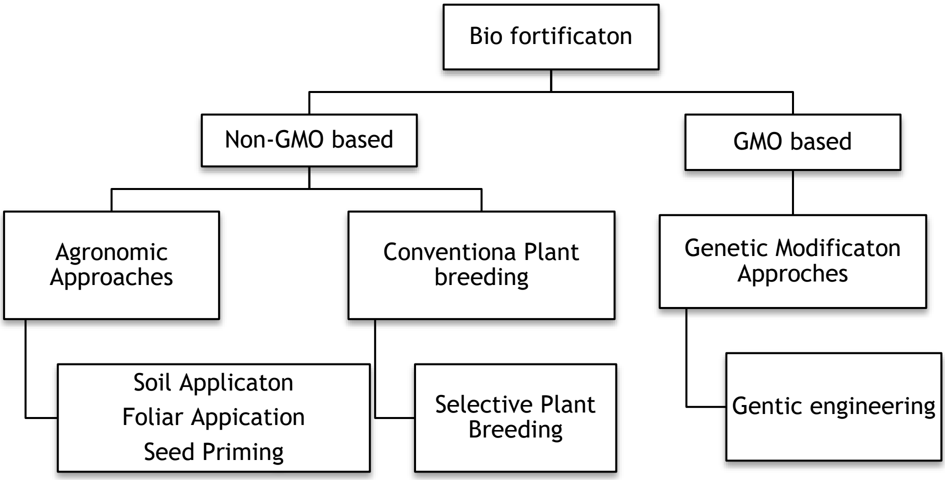

Figure 2: Different approaches of Biofortification

3.1. Biofortification through agronomic practices

This approach involves the application of minerals containing micronutrients to the plant rhizosphere, foliar application and soil inoculation with beneficial microorganism. This increase the Phyto availability of minerals in soil which is often low and gets uptake by plants and translocate to the grains and other parts. Mineral fertilization method is applicable when micro nutrients have good mobility in soil and is such as Se, I and Z but not in for Fe as it has low mobility. Prom-u-thai *et al.*, (2020), found significant higher content of Zn, I and Se in rice grains when cocktail containing Zn, I, Fe were applied as foliar spray in brown rice grain grown under wide range of environment.

3.2. Biofortification through conventional plant breeding

This is the method of enriching food crops through selective breeding. Plant breeders search seed or germplasm bank for existing varieties of crops which are naturally high in nutrients. These high-nutrient varieties are crossed with high yielding varieties of crop, to develop a progeny with high yield along with increased nutrient value.

i. Fe biofortified rice

IR68144 rice Fe biofortified rice which is developed via plant breeding by crossing between IR8 and Taichung (Native)-1 (Virmani and Ilyas-Ahmed, 2008). This rice is high in iron content and able to produce 21 µg/g (2-fold) of iron concentration in brown rice.

ii. Zn biofortified rice

BRRI Dhan-62 was the world's first Zinc fortified rice which was developed using conventional breeding methods Similarly, IET 23832 or DRR Dhan 45, the high zinc rice of India contains 22.6–24.00 ppm in polished grain.

3.3. *Biofortification through genetic modification*

It is an alternative approach applicable when desirable trait for enriching nutrient is not available naturally in the existing germplasm and mean while modifications cannot be achieved by adopting conventional breeding. This method is open to utilize genes from different source like plants, bacteria and other microorganisms.

i. *Iron Biofortified rice*

Enhanced uptake of iron, increase translocation to grain, specialization of Fe storage toward endosperm, decrease of anti-nutrition, an increase of bioavailability of iron are major steps that can be addressed for efficient and targeted genetic biofortification in rice (Mulualem, 2015). To address among these steps some of the popular approaches for facilitating iron biofortification in rice crop through molecular breeding are mentioned as:

Table 6: Different method for iron bio-fortification in rice (Majumder *et al.,* 2019).

S.N.	Biofortification strategies	Increase quantity of iron after bio fortification (brown rice)	Increase quantity of iron after bio fortification (polished rice)
1.	Improving iron storage via ferritin	1.5-2.2- fold	2.0-3.7-fold
2.	Chelation based strategy (via NAS gene)		2.3-4.0-fold
3.	Enhancing iron influx (via OsYSL2 gene)		4.4- fold
4.	Enhancing iron uptake and translocation (via IDS3 gene)	1.3- fold	1.4—fold
5.	Enhancing iron uptake and translocation (silencing OsVITs genes)	1.4- fold	1.8- fold
6.	Manipulation of iron uptakes and translocation regulatiors	2.0-3.8-fold	2.9- fold
7.	Low phytate rice(RNAi silencing of phytic acid)		1.3-1.8- fold
8.	Release of phytic acid bound iron (by phytase gene)	2.0- fold	2.0-6.3- fold
9.	Multiple transgenes combination	6.0- fold	3.4-6.0—fold

ii. *Zinc biofortified rice*

The molecular breeding strategies involved in zinc biofortification are similar to that of iron biofortification. Furthermore, the uptake and homeostasis of zinc and iron are closely linked in cereals. Different approaches for zinc biofortification via genetic manipulation are Overexpression of OsIRT and MxIRT genes in GM rice resulted in increased iron and zinc concentration in rice grains (Majumder, 2019). Similarly, Overexpression of NAS genes makes nicotianamine an interesting target for Zn biofortification. Moreover, biofortifying cereals with NAS alone or in combination with ferritin Over-expression of NA synthase (NAS) by introducing 35S enhancer elements led to 2–3-fold increases in Zn content in paddy (Zheng, *et.al,* 2010).

iii. Golden rice

Golden rice is a variety of rice produced through genetic engineering to biosynthesize beta carotene (Rawat *et.al*, 2013). This rice differs from normal rice as it contains extra genes that were introduced through genetic modification. The rice was invented with the objective to supply Vitamin A to the rice consuming population (Dubock, 2014). In 1999, this rice was invented by Professor Ingo Potrykus of the Institute for Plant Science, Swiss Federal Institute of Technology, Zurich, Switzerland, and Dr. Peter Beyer of the Centre for Applied Biosciences, University of Freiburg, Germany.

Golden rice is genetically modified that contains a high level of beta-carotene and other carotenoids. These are the precursors of vitamin A, beta-carotene change into vitamin A as enters in the body (Tang *et al.*, 2009). It was developed using r-recombinant technology. The technology of biofortification of rice involved the introduction of three genes in rice through *Agrobacterium tumefaciens* viz. two genes from daffodil *Narcissus pseudonarcissus* (phytoene synthase and lycopene beta-cyclase) and one gene from a bacterium *Erwini auredovora* (carotene desaturase) (Beyer et.al., 2002). Golden rice can be beneficial because it serves as a source of supplementary vitamin A and ß-carotene. It can prevent Vitamin A deficiencies that cause blindness, premature death, and xerophthalmia (thickening on conjunctive) (Dubock 2014). ß-carotene is an antioxidant, therefore it helps to protect the body from harmful free-radicles (Grune *et al.,* 2010).

Golden rice provides 1.6-2.0µg ß-carotene/g of dry rice which is not enough to fulfill the recommended daily requirement of vitamin A (Ye *et al.,* 2000.). Similarly, young children are the most vulnerable to vitamin A deficiency, but they do not consume solid food (Hessler *et.al,* 2010). It is believed that as rice contains extraneous genes, it may increase toxicity, decreased nutritional value, gene transfer, and allege city (Zhang, 2016). So, from the above predictions and believes the rice might require further study and research.

CONCLUSION

Along with grain yield and nutrition, quality has also become a primary consideration in rice eating countries. White rice is deficit in several minerals, vitamins, and sometimes becomes unfit for consumption to the patient like diabetics. Consumption of some healthy natural rice like black/purple rice, brown/red rice, and glutinous rice can overcome or minimize this limitation of white rice. Mixing aromatic rice in white rice increases the palatability, fragrance of rice. These landrace cultivars have immense potential to manage the problem of nutrient deficit in rice eating countries but due to their low yielding character, rough texture and poor palatability they are being left behind. To address this limitation of specialty rice landraces there is need of improving the grain yielding character, palatability and texture. Post-harvest processing also determines retention of important micronutrient, fiber and secondary metabolites in rice therefore minimizing the process make rice nutritive as brown rice. The nutritional quality of white/policed rice can be enhanced by the adoption of technology i.e. bio-fortification that includes Agronomic practices, conventional breeding methods and modern genetic engineering. Nutritive rice from conventional breeding methods and agronomic methods has have more scope and wider acceptance as they are away from the controversies of GMO crops. Landraces are valuable source of genetic variation for improvement of rice in future that will create a new avenue for nutritional diversification in rice at lower cost.

REFERENCES

Abbas, A., Murtaza, S., Aslam, F., Khawar, A., Rafique, S., and Naheed, S., 2011. Effect of processing on nutritional value of rice (Oryza sativa). World Journal of Medical Sciences, 6(2): 68-73.

Baek, J. A., Chung, N. J., Choi, K. C., Hwang, J. M., and Lee, J. C., 2015. Hull extracts from pigmented rice exert antioxidant effects associated with total flavonoid contents and induce apoptosis in human cancer cells. Food Sci. Biotechnol, 24: 241–247.

Bean, M. M., Esser, C. A., and Nishita, K. D., 1984.Some physico-chemical and food application characteristics of California waxy rice varieties. Cereal Chem., 61: 475-480.

Berni, R., Id, C. C., Romi, M., Hausman, J., Guerriero, G., and Cai, G., 2018. Agrobiotechnology goes wild: ancient local varieties as sources of bioactives. Int. J. Mol. Sci., 19(8):2248.

Bertoft, E., 2017. Understanding starch structure: Recent progress. Agronomy, 73: 56.

Bestari, N.G., Shrestha, S., Mongcopa, C.J., 2006. Lao PDR: An Evaluation Synthesis on Rice, Asian Development Bank, p 21.

Beyer, P., Al-Babili, S., Ye, X., Lucca, P., Schaub, P., Welsch, R., and Potrykus, I., 2002. Golden rice: introducing the β-carotene biosynthesis pathway into rice endosperm by genetic engineering to defeat vitamin A deficiency. The Journal of nutrition, 132:506S-510S.

Boue, S. M., Daigle, K. W., Chen, M. H., Cao, H., and Heiman, M. L., 2016. Antidiabetic potential of purple and red rice (*Oryza sativa* L.) Bran extracts. J. Agric. Food Chem., 64:5345–5353.

Brinch-Pedersen, H., Borg, S., Tauris, B., and Holm, P. B., 2007. Molecular genetic approaches to increasing mineral availability and vitamin content of cereals. Journal of Cereal Science, 46:308-326.

Buttery, R.G., Ling, L.C., Juliano, B.O., and Tumbaugh, J., 1983a.Cooked rice aroma and 2-acetyl-1-pyroline. J. Agric Food Chem., 31:823-826.

Chaudhary, R.C., and Tran, D.V., 2001. Specialty rices of the world. Italy: FAO, Rome, Italy and India: Oxford IBH Publishers.

Chen, L.J., 2001.Genetic diversity and phylogenetic relationships among cultivated, weedy and wild rice. Thesis for Ph.D. in Yeungnam University, Korea.

Deng, G. F., Xu, X. R., Zhang, Y. Li, D., Gan, R. Y., and Li, H. B., 2013. Phenolic compounds and bioactivities of pigmented rice. Critical reviews in food science and nutrition, 53:296-306.

Dubock, A., 2014. The present status of Golden Rice. Journal of Huazhong Agricultural University, 33:69-84.

Offman, F. D., and Bergman, C. J., 2004. Rice kernel phenolic content and its relationship with antiradical efficiency. Journal of the Science of Food and Agriculture, 84(10): 1235-1240.

Grune, T., Lietz, G., Palou, A., Ross, A.C., Stahl, W., Tang, G., Thurnham, D., Yin, S.A., and Biesalski, H.K., 2010. B-Carotene is an important vitamin A source for humans. The Journal of nutrition, 140:2268S-2285S.

Hansen, T.H., Lombi, E. Fitzgerald, M., Laursen, K.H., Frydenvang, J., Husted, S., Boualaphanh, C., Resurreccion, A., Howard, D.L., De jonge, M.D., and Paterson, D., 2012. Losses of essential mineral nutrients by polishing of rice differ among genotypes due to contrasting grain hardness and mineral distribution. Journal of Cereal Science, 56:307-315.

Insuan, O., Chariyakornkul, A. Rungrote, Y. and Wongpoomchai, R., 2017. Antimutagenic and antioxidant activities of Thai rice brans. J. Cancer Prev. 22:89–97.

Janet, R.H. Luann, K.J.andBienvenido, O.J., 2002. Bioavailability of zinc from cooked Philipinemiiled, undermilled, and brown rice, as assessed in rats by using Growth, Bone, Zinc and Zinc-65 Retention.Journal of Agriculture and Food Chemistry 50: 5229- 5235.

Joshi, B. K., 2017. Local germplasm of rice in Nepal: Diversity, characters and uses. Rice Science and Technology in Nepal. In: D.R. Bhandari, M.P. Khanal, B.K. Joshi, P. Acharya, and K.H. Ghimire, (eds.). Crop Development Directorate (CDD), Hariharbhawan and Agronomy Society of Nepal (ASoN), Khumaltar, 158-178.

Juliano, B.O., 1993. Food and Agriculture Association of United Nations: Rice in Human Nutrition. 3:178-201.

Karkee, S. S. Sah, S. K. Marhatta, S. Dhakal, S. Kandel, M. and Shrestha, J., 2019. Nitrogen uptake and economics of black rice (Oryza sativa L. Indica) under different crop geometries and nitrogen management practices. Archives of Agriculture and Environmental Science 4: 171-176.

Krishnanunni, K. Ramaiah, S. and Anbarasu, A., 2014. Total phenolic content and "in-vitro" antioxidant assay of two medicinal rice varieties - Karungkavuni and Kuzhiadichan. Int. J. Pharma Bio Sci. 5:540–548.

Kumar, N., and Murali, R. D., 2020. Black Rice: A Novel Ingredient in Food Processing. J. Nutr. Food Sci., 10(2): 771.

Kushwaha, U.K.S., 2016. Black Rice. Black Rice Research, History and Development. In: U.K.S. Kushwaha (ed.), 1st edn, Springer International Publishing, 21–47.

Limtrakul, P. Semmarath, W. and Mapoung, S., 2019.Anthocyanins and Proanthocyanidins in Natural Pigmented Rice and Their Bioactivities.In Phytochemicals in Human Health. Intechopen.

Maclean, J.L. Dawe, D.C. Hardy, B. and Hettel, G.P., 2002 Rice almanac. 3rd Edition, International Rice Research Institute, Los Baños, 253.

Majumder, S., Datta, K., and Datta, S. K., 2019. Rice Biofortification: High Iron, Zinc, and Vitamin-A to Fight against "Hidden Hunger". Agronomy 9: 803.

Majumder, S., Datta, K., & Datta, S. K. (2019). Rice biofortification: high Iron, Zinc, and vitamin-A to fight against "hidden hunger". *Agronomy*, *9*(12):803.

Mittal, U. K., Preet., K., Singh, D., Shukla, K.K. and Saini, R.G., 1995. Variability from aroma in some land races and cultivars of scented rice. Crop improve, 22:109-112.

Mulualem, T., 2015. Application of bio-fortification through plant breeding to improve the value of staple crops. Biomed. Biotechnol, 3:11–19. doi: 10.12691/bb-3-1-3.

Nadir, S., Xiong, HB., Zhu, Q. *et al.*, 2017.Weedy rice in sustainable rice production. A review. *Agron. Sustain. Dev.* 37:46.

Noomhorm, A., Kongseree, N., and Apintanapong, M., 1997. Effect of aging on the quality of glutinous rice crackers. Cereal chemistry 74: 12-15.

Panesar, P. S., and Kaur, S., 2016. Rice: Types and Composition Encyclopedia of Food and Health, Academic Press, Oxford: 646-652.

Patil, S. B., and Khan, M. K., 2011. Germinated brown rice as a value added rice product: A review. Journal of food science and technology, 48:661-667.

Pengkumsri, N., Chaiyasut, C., Saenjum, C., Sirilun, S., Peerajan, S., Suwannalert, P., and Sivamaruthi, B. S., 2015.Physicochemical and antioxidative properties of black, brown and red rice varieties of northern Thailand. Food Science and Technology, 35:331-338.

Priya, T. R., Nelson, A. R. L. E., Ravichandran, K., and Antony, U., 2019. Nutritional and functional properties of coloured rice varieties of South India: a review. Journal of Ethnic Foods, 6:11.

Prom-u-thai, C., Rashid, A., Ram, H., Zou, C., Guilherme, L. R. G., *et al.*, 2020. Simultaneous biofortification of rice with zinc, iodine, iron and selenium through foliar treatment of a micronutrient cocktail in five countries. *Frontiers in Plant Science*, *11*.

Puri, S., Dhillon, B., and Sodhi, N. S., 2014. Effect of degree of milling (Dom) on overall quality of rice—A review. International Journal of Advanced Biotechnology and Research, 5(3): 474-489.

Pusadee, T., Wongtamee, A., Rerkasem, B. *et al.,* 2019. Farmers Drive Genetic Diversity of Thai Purple Rice (*Oryza sativa* L.) Landraces. *Econ Bot* ., 73:76–85.

Raghuvanshi, R. S., Dutta, A., Tewari, G., and Suri, S., 2017. Qualitative characteristics of red rice and white rice procured from local market of Uttarakhand: a comparative study. *J. rice Res.*, *10*: 49-53.

Rawat, N. Neelam, K. Tiwari, V. K., and Dhaliwal, H. S., 2013. Biofortification of cereals to overcome hidden hunger. Plant Breeding, 132: 437-445.

Roy, P. Orikasa, T. Okadome, H. Nakamura, N., and Shiina, T., 2011. Processing conditions, rice properties, health and environment. International journal of environmental research and public health, 8:1957-1976.

Saleh, A. S. Wang, P. Wang, N. Yang, L., and Xiao, Z., 2019. Brown rice versus white rice: Nutritional quality, potential health benefits, development of food products, and preservation technologies. Comprehensive Reviews in Food Science and Food Safety, 18:1070-1096.

Saxena, A., 2014. Save the Red Rice: A Unique Gift of Nature. Review Article *Int. J. Curr. Res. Biosci. Plant Biol.*, 2014, 1(4): xx-xx.

Setyaningsih, W., Hidayah, N., Saputro, I. E., Lovillo, M. P., and Barroso, C. G., 2015. Study of glutinous and non-glutinous rice (Oryza sativa) varieties on their antioxidant compounds. In International Conference on Plant, Marine and Environmental Sciences. Kuala Lumpur, Malaysia, 1-2.

Singh, R. K., Khush, G. S., Singh, U. S., Singh, A. K., and Singh, S., 2000. Taxonomy and Origin of Rice Khush (eds), Aromatic Rices, Oxford & IBH Publ, 5-14.

Sukhonthara, S., Theerakulkait, C., and Miyazawa, M., 2009. Characterization of volatile aroma compounds from red and black rice bran. Journal of oleo science, 58(3):155–161.

Tang, G. Qin, J. Dolnikowski, G. G. Russell, R. M., and Grusak, M. A., 2009. Golden Rice is an effective source of vitamin A. The American journal of clinical nutrition, 89:1776-1783.

Upadhyay, A., and Karn, S. K., 2018. Brown Rice: Nutritional Composition and Health Benefits. Journal of Food Science and Technology Nepal, 10:47-52.

USDA, Economic Research Service calculations; 2018.

Virmani, S. S., and Ilyas-Ahmed, M., 2008. Rice breeding for sustainable production. In Breeding Major Food Staples; Blackwell Publishing Ltd.: Oxford, UK.

Wang, W., Li, Y., Dang, P., Zhao, S., Lai, D., and Zhou, L., 2018. Rice secondary metabolites: structures, roles, biosynthesis, and metabolic regulation. Molecules, 23(12): 3098.

Wirjahardja, S., Guhardja, E., and Wiroatmodjo, J., 1983. Wild rice and its control. Proc. Weed Control Rice Conference, IRRI, Philippines.

Ye, X. D. Al-Babili, S. Klti, A. Zhang, J. Beyer, P., and Potrykus, I., 2000. Engineering the Complete ProvitaminA (beta-carotene) Biosynthetic Pathway into (carotenoid-free) Rice Endosperm. Science 287:303-305.

Zhang, C. Wohlhueter, R. and Zhang, H., 2016. Genetically modified foods: A critical review of their promise and problems. Food Science and Human Wellness, 5: 116-123.

Zheng L., Cheng Z., Ai C., Jiang X., Bei X., Zheng Y., Glehn R.P., Welch R.M., Miller D.D., Lei X.G., and Shou, H., 2010. Nicotianamine, a novel enhancer of rice iron bioavailability to humans. PLoS ONE 5(4): e10190.

Zhu, Q. Yu, S. Zeng, D. Liu, H. Wang, H. Yang, Z. Xie, X. Shen, R. Tan, J. Li, H. Zhang, Q. Chen, Y. Guo, J. Chen, L. Liu, Y., and Zhao, X., 2017. Development of "purple endosperm rice" by engineering anthocyanin biosynthesis in the endosperm with a high-efficiency transgene stacking system. Molecular plant, 10: 918-929.