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Review Article

CHAKHAO: SCENTED TRADITIONAL RICE OF MANIPUR (INDIA)

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ABSTRACT

Rice (*Oryza stiva L.*) is the staple food of more than half of world's population and 90% of rice is produced and consumed in Asia. India is centre of diversity of rice and is home to speciality rice such as Basmati and non-basmati type aromatic landraces. Chakhao landraces are speciality rice of Manipur with good aroma and quality. Chakhao literally means delicious rice and is special to people of Manipur as it is use in religious feasts and social ceremonies to prepare special dishes. Pleasant aroma, nutty flavour, glutinous, soft texture on cooking and colour are some of the important qualities of chakhao. Aroma and colour are two of the most important qualities of black scented Chakhao cultivars. Anthocyanin is the compound responsible for beautiful deep purple or black colour in black Chakhao rice. Because of which black chakhao rice has good antioxidant properties and is one of the healthiest food. The review focuses on the different aspects of studies that have been done so far on Chakhao cultivars such as grain quality, nutritional quality, aroma, agronomy, genetic diversity, social value and potential use in food technology.

Keywords: Chakhao, Speciality rice, Quality, Manipur

1. INTRODUCTION

Rice (Oryza sativa L.) is the most important cereal crop in the world. It is the staple food of more than half of the world population, contributing approximately 21% of world per capita calorie intake [1]. About 90% of the world's rice are grown and consumed in Asia [2]. Global rice production for the year 2018 was 782000147 tonnes [3] . China and India are the major rice producers of the world. Rice can be classified on the basis of pigmentation as pigmented and non-pigmented rice. Non-pigmented is consumed by 85% of the world's population but pigmented rice are consumed mainly as a speciality in Asian countries for its unique health benefits and flavour [4] . Few varieties of *Oryza sativa* L. are of uncommon type with unique aroma, flavour, colour (red, purple, black) and composition, termed as 'speciality rice' [5]. In India aromatic rice is classified as basmati and non-basmati type. Majority of the aromatic indigenous rice varieties are small and medium grained [6].

Manipur is a state situated in the north-eastern part of India covering an area of 22,327 sq. km. The state is located between 98°03′ E and 94°68′ E longitude and 23°83′ N and 25°68′ N latitude. Topographically, the state consists of two geographical regions: the valley and the surrounding hills. The valley has an oval shape covering an area of 2,230 Km^2 and is known as the rice bowl of the state [7]. The state has rich resource of rice germplasm which includes pigmented, aromatic, glutinous and medicinal cultivars. The word for scented rice in Manipuri is 'Chakhao' which literally means delicious rice (chak = rice, ahaoba = delicious) [8]. Scented rice of Manipur are described by farmers based on grain colour as Chakhao amubi for black scented rice, Chakhao angangba for red and Chakhao angouba for white scented rice. Among them, Black chakhao rice is the most popular and highly priced. Black chakhao rice are characterized by their exquisite purple to black colour, sweet aroma and nutty flavour. They may be short, medium or long grained. Chakhao rice are special to people of Manipur as they use them to prepare dishes in religious feasts, social ceremonies and festivals [8] . Chakhao is not consumed as the main meal or staple food but is taken as dessert or in sweetened form. The unique black colour of chakhao is due to high deposition of anthocyanins in the outer pericarp, seed coat and aleurone layer [5]. A handful of this rice when cooked with white rice will change the colour to purple. Anthocyanins are flavonoid compounds reddish to purple in colour which are responsible for strong

antioxidant properties in pigmented rice [9]. Black chakhao cultivars are receiving more attention because of their sensory properties, superior nutritional quality and potential health benefits. Most of the research works on Chakhao started after 2010. Several researchers have work on the nutritional quality, grain quality of chakhao cultivars [10-13]. Studies have been made on quantification of phytochemical compounds with antioxidant potentials [10-12, 14]. Very little studies has been done on aroma[15]. There has been some studies on genetic diversity, population structure, breeding of chakhao cultivars [7, 8, 16, 17]. Black rice has higher minerals, proteins and bioactive compounds as compared to white rice varieties. Chakhao rice have immense potential as a functional food as well as food colorant. The present review paper focuses on different aspects of studies that has been done on Chakhao cultivars such as, grain quality, nutritional quality, aroma, agronomy, genetic diversity, social value and potential use in food technology of Chakhao rice varieties with more emphasis on the black rice cultivars of Manipur.

2. HISTORICAL PERSPECTIVE

'Chakhao' is believed to have come with the people of Manipur, particularly the Meiteis or Meeteis when they first settled in Manipur. According to Poireiton khunthokpa, one of the earliest historical text of Meiteis, refers to the adventures of Chingkhong Poireiton, a coloniser from the East at the turn of the Christian era[18]. During his reign his kingdom was known as Poirei-lam (land of Poreiton) and the people as "Poirei Meitei". Poireiton khunthokpa is the first literary text that mention about paddy cultivation in valley of Manipur and how black rice chakhao poireiton came to be cultivated in Manipur[19]. The Archeological and literary evidences have shown that ancient Meitei were practising shifting cultivation before they practise wet land cultivation[20]. Chakhao poireiton was named after King Poireiton because he was the first to domesticate Chakhao in Manipur during 38-18 B.C. Black rice cultivars has been grown in Manipur and have evolved through selection by farmers for thousands of years. Pigmented Chakhao cultivars are not taken as staple food and there is a cultural taboo to not abandon its consecutive cultivation before three years [21]. According to Potsangbam Devakanta, national awardee "Protection of Plant Varieties and Farmers Rights Act Conservation award" 2012, there are about 20 varieties of black rice grown by the farmers in Manipur of which Poireiton is the best variety. Some of the black or purple scented rice grown in Manipur are Chakhao Poireiton, Chakhao Amubi, Wairi Chakhao, Khurkhul Chakhao, Pong Chakhao and Chakhao Sempak. Examples of red scented rice cultivars are Chakhao Anganba and Langphou Chakhao and white scented types includes Chakhao Manam Nungshibi and Chakhao Angouba [15]. Some pigmented Chakhao cultivars grown in hills are Manui Kazik, Napneng dengmei, Athebu ium, Athebu evum and Thomuh [22]. Many landraces has already been lost due to introduction of high yielding hybrid varieties. In the past few years, there has been increasing interest in chakhao farming because of increase in knowledge about the health benefits of black rice. Black rice cultivars are cultivated both on hills and valleys of Manipur and even successful cultivation of Chakhao poireiton on floating biomass of Loktak lake have been reported. Recently Chakhao has bagged the Geographical Indication (GI) tag and is registered under GI certificate number 364.

3. AROMA

Aromatic rice are special group of rice with nutty or popcorn like aroma. They possess scent in their plant parts and grain [23]. In most countries aromatic rices commands higher prices in the market [6]. 2-acetyl-1-pyrroline was identified as the key aroma or flavour compound in rice which is responsible for popcorn like aroma [25, 26]. More than 500 volatile compounds has been identified [26]. A mixture of odor active compounds is responsible for aroma in rice which includes a series of compounds like aldehydes, ketones, organic acids, alcohols, esters, hydrocarbons, phenols, pyrazines and other compounds [27] . Qualitative and quantitative difference in concentration of odor active compounds is responsible for difference in flavors among different rice varities [28]. 50% of the scented rice of Manipur belongs to indica group while the remaining 50% belongs to a mixture between japonica and indica [29]. Black chakhao rice has nutty flavour and has pleasant aroma. Very little research has been done in understanding the volatile compounds and aroma compounds associated with Chakhao rice. Using GC-MS analysis, 26 volatile aroma compounds has been identified in Chakhao poireiton and 11 volatile compounds from Chakhao amubi [15]. The most abundant aroma compounds in Chakhao poireiton were n-hexadecanoic acid and octadec-9-enoic acid. In Chakhao amubi, 17-pentatriacontene, 13-octadecenal (Z) and hexadecenoic

acid eicosyl ester were the most abundant.2-Acetyl-1-pyrroline, guaiacol, indole, and *p*-xylene have been reported as compounds responsible for aroma in other black rice varieties [28]. Hexanal, (E)-2-nonenal, octanal and heptanal are some of the major odor active compounds identified in black rice [30]. So, there is a variation in the volatile composition responsible for aroma and flavour of black rice varieties. Further studies with more sophisticated techniques to confirm the presence of 2-acetyl-1-pyrroline and other aroma compounds found in black rice needs to be investigated.

Fig.1: Some common Chakhao Cultivars. A) Chakhao amubi B) Chakhao Poireiton C) Chakhao angangba D) Chakhao angouba

4. GRAIN QUALITY

Grain quality traits encompasses several traits such as physical appearance, cooking and sensory properties and, more recently, nutritional value [31]. Grain quality is an important criteria in variety selection and breeding. The size and shape of Chakhao poireiton and Chakhao amubi has been classified based on length by breath ratio (L/B) as long slender and long bold [10,11].Physical properties of two black chakhao cultivars in brown [11] and milled form [10] is shown in table-1.It can be seen from the previous studies that Chakhao amubi and Chakhao poireiton have similar physical properties. Chakhao poireiton has lower 1000 kernel weight but higher L/B ratio and 1000 grain volume than Chakhao amubi [10,11].

Cooking and eating quality of rice depends on the physico-chemical properties of starch which makes up 90% of milled rice. Several factors such as gelatinization temperature, amylose content, gel consistency, water absorption, volume expansion determines the cooking and eating qualities of rice [2,6] . Because of the presence of fibrous bran layer, cooking time of chakhao takes 40-43 min [11]. Very low amylose content has been reported in Chakhao cultivars which further decreases in milled polished form. Chakhao amubi and Chakhao poireiton in brown rice form has amylose content of 6.5 % and 5.39% respectively [11]. Chakhao amubi and Chakhao poireiton in milled rice form has amylose content of 2.9% and 2.2% respectively [10]. Another researcher also reported similar result while comparing three Chakhao cultivars i.e. Chakhao amubi, Chakhao poireiton and Chakhao anganba. The amylose content of the three cultivars in brown rice form ranges between 1.93-3.16% with the lowest in Chakhao

angangba and highest in Chakhao amubi. In milled form the amylose content ranges between 3.98-6.11% with the highest in Chakhao amubi and lowest in Chakhao angangba [12]. The two cultivars have soft gel consistency with gel length 119 mm-144 mm, indicating that the two cultivars will have soft texture after cooking [10]. The two cultivars also showed high gelatinization temperature of 78.1-83.7°C. Thus, most Chakhao cultivars are glutinous or waxy when cooked with very low amylose content and high gelatinization temperature. The black chakhao cultivars were reported to have similar cooking characteristics in terms of water uptake, swelling capacity, gruel solid loss, amylopectin content [11]. Colour characteristics of different Chakhao cultivars showed significant variation and is shown in Table-2. XRD analysis of Chakhao rice exhibit A type X-ray diffraction pattern with peaks at 2θ = 15.1°, 17.1°, 18.2° and 23.0°. Highest crystallinity was observed in Chakhao angangba in both raw and polished form and lowest in Chakhao amubi in both raw and polished form (Table-2). Lightness (L*), redness (a*) and yellowness (b*) are strong indicators of bioactive compounds [32].

Table 1: Physical properties of Chakhao cultivars.

Rice cultivars	Bulk density (g/cm^3)	True density (g/cm^3)	1000 Kernel weight	Length (mm)	Breadth (mm)	L/B	1000 grain volume	References
Chakhao poireiton	0.54	1.09	16.56	6.51	2.02	3.25	_	[10]
Chakhao amubi	0.53	1.03	22.32	6.21	2.6	2.38	_	[10]
Chakhao poireiton	0.83	_	19.45	6.77	2.09	3.24	60.16	[11]
Chakhao amubi	0.85	_	22.14	6.24	2.25	2.77	58.83	[11]

Table 2: Colour characteristics and crystallinity of Chakhao rice cultivars

Rice cultivars		L*	a*	b*	Crystallinity (%)	References
Chakhao poireiton	(milled)	48.58	2.47	1.77	_	[10]
Chakhao amubi	(milled)	62.12	4.41	8.79	_	[10]
Chakhao amubi	(raw)	61.53	2.21	2.86	9.56	[12]
Chakhao amubi	(Polished)	84.34	1.58	1.72	9.18	[12]
Chakhao poireiton	(raw)	64.52	3.45	3.49	10.32	[12]
Chakhao poireiton	(polished)	75.36	2.68	0.24	10.08	[12]
Chakhao angangba	(raw)	74.41	7.68	11.29	10.75	[12]
Chakhao angangba	(polished)	88.64	1.46	3.25	10.34	[12]

Starch is the major component of rice and is composed of α- glucans i.e. amylose and amylopectin. Amylose is the major factor influencing various physiochemical properties of rice starch [33]. The variation in amylose and amylopectin ratio is responsible for variation in thermal, texture, rheological and cooking properties of rice varieties. The structure, functional and thermal properties of starch of three chakhao types *i.e.* Chakhao amubi, Chakhao poireiton and Chakhao angangba. Variation was observed in moisture content (9.39-10.58 g/100 g starch), ash (0.47-0.57 g/100 g starch), protein (0.27-0.46 g/100g starch) and fat content (0.04-0.09 g/100 g) of starch. Chakhao poireiton and chakhao angangbi was classified as waxy, as their amylose content was less than 2% i.e.1.98% and 1.93% respectively. Chakhao amubi was with very low amylose content (3.16%).SEM analysis of the rice starches revealed the shape to be polyhedral with irregular small size and smooth surfaces. Morphologically the rice starches were similar. XRD analysis of rice starch powder exhibit A-type crystalline patterns with peaks at 2θ = 15.1°, 17.1°, 18.2° and 23.0°[34]. Similar A-type diffraction pattern has been reported in other waxy black rice varieties [35,36]. Pasting viscosity, swelling power and solubility, crystallinity of the rice starches varied significantly among the rice starches. Understanding physiochemical properties of rice is necessary evaluation of grain quality and for possible application in food industry [36].

5. NUTRITIONAL QUALITY

Rice consists of the hull and the caryopsis or grain, the hull is the outermost layer which constitutes 20% of the rough rice weight, composed of silica and cellulose.

Brown rice is obtained when the hull is removed through hulling process. In brown rice the bran layer is intact and is rich in protein, fibre, minerals, vitamins and other phytochemicals [37], followed by protein and fat. Pigmented rice is usually consumed unpolished or semi-polished. Carbohydrates make up the major composition of rice which is predominantly starch followed by protein and fat. Carbohydrates are the major source of energy in countries where rice is consumed as staple food. Rice protein is highly digestible and has high proportion of Lysine [38, 39]. Fat or lipids are present mainly in the bran layer of rice so they are greater in brown rice than milled rice. The main lipids found in rice are linoleic acid, oleic acid, palmitic acid, stearic and linolenic acids which are saponifiable lipids [38,40]. Extensive work has been done in the area of nutritional quality of chakhao rice especially Chakhao poireiton, Chakhao amubi and Chakhao anganba. Proximate composition of some Chakhao cultivars as reported by different researchers is shown in Table 3.

Rice is not a rich source of minerals but contain appreciable amount of minerals which are concentrated in the outer bran layer [38]. Pigmented Chakhao are good source of protein, fibre, amino acid and minerals. Red rice are rich in zinc, iron while black rice are especially rich in protein, fat and crude fibre [40]. Minerals and vitamins are beneficial to health and help in prevention of malnutrition related diseases. Black rice cultivars are a good source of vitamins, minerals and fibre [41]. Mineral contents of different chakhao cultivars are shown in Table-4.

Phytochemicals are bioactive compounds produced by plants majority which are also known as secondary metabolites. Phenolics, flavonoids, anthocyanins, sterols, oryzanols and vitamin E are some of the important bioactive compounds present in rice. Pigmented rice cultivars are usually consumed without polishing so they are packed with many health beneficial nutrients. Important phytochemical content and antioxidant activity of Chakhao cultivars has been listed in Table 5.

Table 3: Proximate composition of Chakhao cultivars.

Rice cultivars	Moisture %	Fibre %	Ash%	protein%	Carbohydrate %	Fat%	Ref.
Chakhao amubi (brown)	10.8	1.4	2.8	9.05	75.3	1.9	[10]
Chakhao poireiton (brown)	12.1	1.18	1.9	10.4	72.5	2.94	[10]
Chakhao amubi (milled)	11.6	0.3	0.5	8.8	78	1	[11]
Chakhao poireiton (milled)	13.5	0.2	0.5	6.6	77.2	2	[11]
Chakhao amubi (raw)	11.4	_	0.83	8.75	74.67	3.33	[12]
Chakhao amubi (polished)	8.72	_	0.33	8.48	82.13	0.41	[12]
Chakhao poireiton (raw)	12.05	_	1.79	7.77	74.38	3.73	[12]
Chakhao poireiton (polished)	8.54	_	0.57	7.45	83.27	0.34	[12]
Chakhao angangba (raw)	11.12	_	1.38	5.57	78.24	3.05	[12]
Chakhao angangba (polished)	8.17	_	0.81	5.29	85.57	0.21	[12]

Table 4: Mineral content of different Chakhao cultivars (mg/Kg)

Rice cultivars	Fe	Cu	Na	Mg	Ca	Cr	Zn	Mn	Ni	K	P	S	Cl	Ref.
CA (raw)	34.3	5.3	_	_	_	_	62	23.6	_	_	_	_	_	[11]
CP (raw)	26.6	5.3	_	_	_	_	43	25.6	_	_	_	_	_	[11]
CA (raw)	88.8	33.4	_	377.2	136.2	_	53.9	38.8	_	1606.6	2062.1	976.1	63.4	[12]
CA (polished)	26.2	26.2	_	106.6	53.6	_	24.6	20.1	_	566.1	718.5	847.4	39.6	[12]
CP (raw)	47.2	27.5	_	387.6	114.6	_	42.4	42.7	_	1843.6	2529.7	916.5	60.6	[12]
CP (polished)	30.6	20.1	_	215.8	63.2	_	24.7	21.8	_	966.4	1401.6	795.8	44.3	[12]
C (Raw)	57.1	30.6	_	379.1	77.6	_	34.9	23.6	_	1546.8	2248.1	743.5	35.7	[12]
C (polished)	24.5	24.1	_	56.8	42.5	_	20.2	14.5	_	449.2	456.7	657.7	28.6	[12]
CA (raw)	0.42	0.03	3.26	3.43	57.68	0.14	0.24	0.03	0.07	_	_	_	_	[13]

Where CA= Chakhao amubi, CP = Chakhao poireiton, C = Chakhao angangba, Ref. = References.

Table 5: Phytochemical and antioxidant activity of chakhao cultivars

Rice cultivars	Phenolics (mg/100g)	Flavonoids (mg/100g)	Anthocyanins (mg/100g)	DPPH %	FRAP values (mM/100g)	Ref.
Chakhao amubi (6% milled)	579	200.5	1.81	96.43	5.45	[10]
Chakhao poireiton (6% milled)	245	123.75	35.87	94.19	2.59	[10]
Chakhao amubi (brown)	500	_	69.2	69.73	_	[14]
Chakhao poireiton (brown)	577	_	74	70.28	_	[14]
Chakhao amubi (brown)	19.75	_	_	72.52	_	[11]
Chakhao poireiton (brown)	62.33	_	_	59.02	_	[11]
Chakhao amubi (brown)	1000	335	_	89.28	_	[12]
Chakhao amubi (9% polished)	100	30	_	6.5	_	[12]
Chakhao poireiton (brown)	775	325	_	84.77	_	[12]
Chakhao poireiton (9% polished)	112	60	_	6.11	_	[12]
Chakhao angaoba (brown)	1055	349	_	92.67	_	[12]
Chakhao angaoba (9% polished)	145	18	_	6.17	_	[11]

Recent study on total phenolics, flavonoids and antioxidant assay of Chakhao amubi have also shown that Chakhao amubi has high phenolics, flavonoids content with values 126.9 mg/100g, 121.7 mg/100g respecttively and IC_{50} value of 1028.9µg/ml respectively. HPLC analysis of anthocyanin extracts of Chakhao poireiton and Chakhao amubi has confirmed that four anthocyanins i.e. delphinidin-3-galactoside, delphinidin-3-arabinoside, cyanidin 3-galactoside and cyanidin 3-glucoside are the main anthocyanin compounds present in Chakhao poireiton and three anthocyanins delphinidin 3-galactoside, delphinidin 3-arabinoside and cyanidin 3-galactoside are the main anthocyanins in Chakhao amubi [14]. Cyanidin-3-glucoside and Peonidin-3-glucoside are the most common anthocyanins in coloured rice [9]. Phenolics belong to class secondary metabolite compounds which are known to have bioactive properties. Both anthocyanins and flavonoids come under phenolics. Pigmented rice have high phenolic acids content and ferulic acid was the most abundant free phenolic compound [4]. While another researcher reported that Procatechuic acid was predominant in the free form and ferulic acid was predominant in bound form [42] .Other common phenolics present in rice are protocatechuic acid, synaptic acid, vanillic acid, and p-coumaric acid [43]. LC-MS analysis also revealed the presence of oryzanol, linoleic acid, linolenic acid, ferulic acid, protocatechuic acid and dehydroxy myricetin in Chakhao amubi [13]. All these phytochemicals are responsible for nutraceutical properties such as antioxidant, anticancer, anti-inflammatory, anti-diabetic, anti-allergic and anti-atheroscelrosis.

6. AGRONOMY

According to the data of Agriculture department, Manipur 2016-2017, the total area under rice cultivation is 0.19 million hectares, with total rice production of 4.31 lakh tonnes. Jhumming and terrace farming are the main feature of hill agriculture of the state covering an area of 88700 ha under rice cultivation. Paddy is the most important cereal crop in Manipur and the area under rice cultivation is 0.22 mha (3.4 mha in North East India) which covers both irrigated and rainfed areas [44]. In Manipur, black rice is a Kharif crop, cultivated in the month of June-July and harvested in the month of October-November. In Manipur, 10% of paddy area is under Chakhao cultivation. The black chakhao cultivars are quite tall in height. Majority of Chakhao cultivars ranges in height between130-165 cm and flowering is initiated between 108 to 116 days [21]. Chakhao cultivars are poor yielding (1.3-1.8 tonnes/hectare). Farmers usually practise organic farming of Chakhao cultivars because chemicals and farmyard manures cause enhance vegetative growth and increase production of chaffy grains. Also requires less labour inputs such as ploughing, weeding and care [21]. Chakhao rice is resistant to certain rice diseases such as sheath rot, foot rot, stem rot, narrow brown spot, false smut,bacterial leaf blight and resistant to pests such as bacterial leaf streak and rice insect pests such as stem borer, case worm, thrips, rice skipper, green horned caterpillar, green semi looper and rice bug. The reason for its resistence may be attributed by its high phenolic and anthocyanin content [14]. Chakhao cultivars can grow well on stressful condition such as poor soil nutrient and

water, drought and stress resistant. However are poor yielding as compared to hybrid varieties and traditional varieties [21].

7. DIVERSITY AND BREEDING OF CHAKHAO LANDRACES

In the past few years there has been progress in germplasm collection, characterization, studies on genetic divergence and breeding. Knowledge on genetic divergence and relationship among genotypes is important for developing more effective breeding and conservation programs [8]. Genetic divergence of 32 indigenous rice germplasms has been studied using based on twelve morphological characters and Mahalanobis D^2 statistics [7]. Genetic diversity of 37 Chakhao based on genotyping with 47 microsatellite markers has revealed that high gene diversity occurs within the Chakhao population. Also based on genetic structure analyses, Chakhao rice accessions was divided into six subgroups [8]. Genetic diversity of 6,984 accessions of rice from North-East India has been accessed using 36 SNP markers with 549 accessions from Manipur [45]. Another study with 40 simple sequence repeat (SSR) markers with an average of 8.03 alleles per locus has been used to study 107 aromatic accessions from North-east India. The rice accessions were classified into three distinct population clusters.ie.P1, joha rice accessions from Assam, tai rices from Mizoram and those from Sikkim; P2, chakhao rice germplasm from Manipur; and P3, aromatic rice accessions from Nagaland. Based on diversity and population structure studies of rice gerplasms from North-eastern India, aromatic accessions from Assam, Manipur and Sikkim were assigned to Indica group while the accessions from Nagaland exhibited close association with Japonica. The tai accessions of Mizoram along with few chakhao accessions collected from the hill districts of Manipur were identified as admixed [16]. 27 standard microsatellite data from 171 rice landraces from six states were analysed to understand their genetic diversity and population structure of six North-Eastern states. From the study Chakhao accessions of Manipur has been assigned to indica and admix which supports the result of Roy et al (2015) [17] . A novel rice hybrid of "Chakhao Amubi and Basmati 370" has been successfully developed to improve yield and provide better grain quality rice having high nutra-ceutical properties using anther culture development techniques of homozygous breeding lines of double haploid [46].

8. CHAKHAO IN FOOD APPLICATIONS

Due to superior nutritional quality, nutraceutical properties and anthocyanin content black chakhao cultivars has immense potential as a functional food and in food industry. Chakhao based supplementary food, Chakhao based noodles, better quality and healthier gulab-jamun has been prepared using black Chakhao [47]. Black Chakhao rice has good potential for use in brewing industry. A protocol has been developed for brewing Chakhao poireiton with 100% malted rice. The apparent fermentability of rice worts of Chakhao was 69.5%, yield of beer was 3.28% ABV (Alcohol by Volume). Black rice beer has higher polyphenolic content than white rice beer and has orange -red hue due to extraction of anthocyanin pigments (2.84 mg/ L). The oxidative stability of 100% rice beer was stable and the beer when blended with control barley malt derived lager in varying proportions, the oxidative stability was improved [48]. Chakhao has been use to produce other food items such as Chakhao cake, Chakhao muffin, Chakhao tea and Chakhao bujia etc. Pigmented Chakhao rice has good potential for use as natural food colorant, a healthy alternative to synthetic food colorants.

9. SOCIO CULTURAL VALUES

Chakhao rice is of special significance in the life of Manipuri people. Chakhao is use to prepare unique delicacies in religious and cultural ceremonies. From nutritional point of view rice flour is an ingredient in numerous traditional food which may be due to absence of allergenic proteins, low calcium and gluten free [49]. Cooked chakhao rice is served with 'Kheer' (a dessert) in usob (religious feast). It is also served as Chakhao Kheer in Chakumba (First rice eating ceremony). It is also use to prepare ethe tan (Flatbread or local puri), Kabok afaba (puffed rice prepared directly from kernel), Kabok akhingba (puffed rice prepared from boiled rice), Kabok Khoidum (puffed rice mixed with sugarcane juice ,shaped as ladoo), Chengpak (flakes), utong chaak (a special dish were rice is cooked in bamboo stick), Buhman sang (A local delicacy prepared from Buhman landraces in Churachandpur) [21,8]. Black Chakhao is also used to prepare Chakhao atingba (traditional beer) which is one of the most relished beers among the meiteis. Pregnant women are served with black rice, a few days before delivery. It is consumed in small quantities by people suffering from diabetes, commonly called Ising pukchat. The chakhao straw is preferred for thatching houses because of its length and durability.

The husks is also used as farmyard manure and livestock feed [21].

10. CONCLUSION

Nutritional quality and nutraceutical properties of pigmented Chakhao cultivars especially the black cultivars have renewed interests and utilisation in food applications. Manipur has rich resource of non-basmati type locally adapted aromatic and quality landraces but a lot needs to be done to explore and study about these cultivars for proper understanding of its quality, characterization, conservation and application. Aroma of Chakhao needs to be properly investigated and its potential as a functional food and biological activities deserves more attention from researchers.

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