QUALITY EVALUATION OF KAU RED RICE (*Oryza sativa* L.) VARIETIES

By
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(2014-16-105)

THESIS

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DECLARATION

I, hereby declare that the thesis entitled"**Quality evaluation of KAU red rice (*Oryza sativa* L.) varieties**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed during the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that the thesis entitled**"Quality evaluation of KAU red rice (*Oryza sativa* L.) varieties"** is a bonafide record of research work done independently by **Mrs. Revathy G. Nadh** under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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INTRODUCTION

1. INTRODUCTION

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'Rice is life' for more than half of humanity in the world. Rice is the grain which has shaped the history, culture, diet and economy of billions of people in the world. Rice is considered sacred and the ritual of harvesting rice has been linked to Asian culture and traditions for centuries. More than 3.5 billion people depend on rice for more than 20 per cent of their daily energy requirements. Rice provides 21 per cent of global human per capita energy and 15 per cent of per capita protein. Asia accounts for more than 90 per cent of world's rice production and consumption. According to FAO (2017) the global paddy production in the year 2015-16 was 491.6 million tonnes.

India has a long history of rice cultivation. In India, rice is cultivated under diversified agro climatic conditions from upland hills of Himalayas in Kashmir to low-lying Kuttanad areas of Kerala (Boopathi *et al.*, 2012). Within the country, rice occupies one quarter of the total cropped area under production, contributing about 40 to 43 per cent of total food grain production. India is the second largest producer and consumer of rice in the world and accounts for 22.3 per cent of global production. The most sizable share in India's total cereal export (64.4 per cent) is occupied by rice during 2013-2014 (Khatkar *et al.*, 2016). Most of the rice is exported in milled form (77 per cent) and about 15 per cent are exported as parboiled rice. Thus, rice plays a vital role in the national food and livelihood security (Sharma, 2014).

Paddy cultivation is a part of the proud culture of Kerala state. Kuttanad is called as rice bowl of Kerala because of larger area of rice under cultivation. Thrissur and Palakkad are the other two places in Kerala where large scale rice cultivation is being done. During 2014-2015, rice production in Kerala was 5,49,275 tonnes (Mukesh, 2016).

Rice is adapted to a wide range of geographical, ecological and climatic regions. According to Vivekanandan (2012) India has 100,000 traditional varieties still in use by farmers and another 3,00,000 have become extinct. *Kattamodan,*

Karuthamodan, Chuvannamodan, Kavunginpoothala and *Thekkencheera* are some of traditional red rice varieties in Kerala. The popular and high yielding red rice varieties in Kerala include *Uma, Jyothi, Kumbhan, Karuna, Harsha, Deepthi, Makaram, Kanchana, Aathira* and *Aiswarya. Vyttila-1, Vyttila-2, Vyttila-3, Vyttila-4 and Vyttila-5.*

The colour of rice is attributed to the colour of its bran. Rice with white, red, purple, black, brown and yellow bran colour are cultivated in the traditional rice growing areas of Asia. Rice with a red bran layer is called red rice. In Ayurveda, the traditional Indian medical system, coloured rice is called *shastika* rice and claims to restore imbalances in the human body (Bhat and Riar, 2015). Red and black rice varieties contain the pigment anthocyanins which have medicinal properties like anti-oxidative, antiinflammatory and anticarcinogenic effects.

About one-fifth of the world's rice is parboiled. Parboiling is an ideal post-harvest treatment which involves, soaking, steaming and drying of paddy, in order to obtain better consumer appeal and value addition (Zossou, 2010). Parboiling improves the milling recovery and increases the grain hardness which results in less breakage during milling. The process brings about significant changes in the physico-chemical and cooking characteristics of rice grain. Parboiling fills the void spaces and cements the cracks inside the endosperm, making the grain harder and minimising internal fissuring and thereby breakage during milling (Bellousi *et al.,* 2010). On parboiling, many vitamins diffuse from the bran to endosperm hence parboiled white rice is 80 per cent nutritionally similar to brown rice (Akther *et al.,* 2015). The starches in parboiled rice become gelatinised, making it harder and glossier than ordinary rice. Keralites prefer parboiled rice for table rice and whereas other white varieties are preferred for making food products.

Physical qualities after parboiling determine the market value of rice. Grain quality involves grain appearance, size and shape of the grain, behaviour

upon cooking, taste, tenderness and flavour of cooked rice. Consumer's choice of rice varieties is largely based on grain and cooking qualities. A large void exists in basic knowledge about the physical and functional components of most of the rice varieties. Knowledge on the physico - chemical and cooking qualities of rice is essential for expanding industrial applications and to produce superior quality rice products. Parboiling improves all these qualities and heightens their consumer acceptance.

Although red rice is considered as nutritionally superior, its acceptance in Kerala is mainly confined to table rice. Suitability of red rice varieties for traditional preparations has to be evaluated for popularisation of these varieties. However, the effect of changes in the quality of rice and rice products prepared with parboiled rice needs investigation. Hence, the present study entitled "Quality evaluation of KAU red rice (*Oryza sativa* L.) varieties" has been undertaken with the following objectives.

1. To study the effect of parboiling on the physical, biochemical, nutritional, cooking and organoleptic qualities.

2. To assess the suitability of rice varieties viz. *Kanchana, Aiswarya, Samyuktha, Aathira* and *Ezhome-4* for the preparation of selected traditional food products.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Literatures pertaining to the study entitled 'Quality evaluation of KAU red rice (*Oryza sativa* L.) varieties' are reviewed under the following headings.

2.1 Rice – The global staple

2.2 Nutritional and health benefits of red rice

2.3 Effect of parboiling on rice grain quality

2.4 Rice based value added products

2.1 Rice - The global staple

'Rice is vitality, rice is vigor too and rice indeed is the means of fulfilment of all ends in life. All gods, demons and human beings subsist on rice'

(*Krishi-Parashara*)

Rice is the sacred grain which shaped the tradition, culture and food habits of billions of people in the world. Every third person on earth, eats rice every day in one form or another. Rice has been depicted as the 'grain of life', as it is closely knitted with the day to day life of more than half of the humanity in the world. It is the most widely consumed staple food of the world's human population (Noonari *et al.,* 2015). It is an integral part of social life and is associated with rituals, festivals, religious offerings and is also a symbol of prosperity.

Rice plays a fundamental role in world's food security, poverty alleviation and socioeconomic development. Food security in Asia has traditionally focused on rice, its production, marketing and consumption. Rice is cultivated in 157 million ha in the world, of which 90 per cent of the area is in Asia. According to the FAO (2013) 80 per cent of the world rice production comes from seven countries. The top ten countries of the world listed for their rice production are China (32.7%), India (26%), Indonesia (10.2%), Bangladesh (7.5%), Vietnam

(6.8%), Thailand (5.3%), Myanmar (4.8%), Philippines (2.8%), Brazil (2.0%) and Japan (1.9%).

Rice production is an important source of livelihood for around 140 million rice farming households and for millions of rural poor who work on rice farms as hired labour. Nearly a fifth of the total household expenditure on average is spent on rice – the staple of poor in Asian countries. India has become the world's second largest rice producing nation with largest rice harvesting area. India has the largest acreage of 44 million ha under rice with a production of 100 million tonnes (FAO, 2014).

In India, rice is a major food staple and a main stay of food security and economy of rural population. It is mainly cultivated by small farmers with holdings of less than one hectare. Rice is also a "wage" product for human resources in India. Around 65 per cent of total population in India depends on rice and it accounts for 40 per cent of total food production (Bishwajith *et al.,* 2013).

Rice is the most versatile cereal crop that provides 27 per cent of the dietary energy and 20 per cent of the dietary protein intake (Kennedy and Choudhary, 2001). Mishra and Sinha (2012) reported that rice provides 23 per cent of human per capita energy and 16 per cent of per capita protein. The author also indicated that for the majority of Asians who eat rice, the total intake is 2531 calories per person per day with 35 per cent comes from rice.

According to Timmer *et al.* (2010) 29.8 per cent of total calories of Indians comes from rice. According to FAO STAT (2013) rice provides 21 per cent of global human per capita energy and 15 per cent of per capita protein. For populations living in many developing countries, rice contributes to the greatest percentage of calories and protein (Vethavarshini *et al.,* 2013).

The global rice per capita consumption was 45-50 Kg in 1961 and the consumption level peaked above 65 kg during 2000 and then declined to 64 Kg during 2010 (Timmer *et al.,* 2010).

The monthly household consumption of cereals in India during 2004-2005 was 85 per cent in rural area and 90 per cent in urban area (NSSO, 2007). Monthly per capita expenditure on cereals in Kerala during 2007 was Rs. 136.09 in rural area and Rs. 141.4 in urban area as reported by NSSO (2008). During 2012, the per capita availability of rice in India is 69.4 Kg per annum (Agricultural statistics, 2013). Indian rice consumption in 20132014 was estimated at 95 million tonnes with a modest increase of 1.5 per cent from previous year, which is almost equal to the population growth rate of 1.4 per cent per annum (Khatkari *et al.,* 2016). The author also reported that the monthly per capita consumption of rice in India declined from 6.38 to 5.98 kg and from 4.71 to 4.49 kg during the period from 2004-05 to 2011-12 in rural and urban areas respectively.

It is foreseen that world population may exceed 8 billion by 2025 and about 765 million tonnes of rice will be needed to meet the demand of the growing population (Premkumar *et al.,* 2012). It is predicted that India needs to produce 115 mt of rice, 225 mt of food grains and has to achieve an agriculture GDP growth of 4 per cent by the year 2020 (Sheshagiri, 2014).

Hari (2008) reported that rice, the staple of Kerala is the most favoured grain and is widely cultivated in Kerala. The monthly per capita rice consumption in Kerala was 8.17 kg in rural area and 7.66 kg in urban area. According to NSS (2005), in Kerala monthly average expenditure for cereals per person per day was Rs.108.89 in rural area and Rs.101.10 for urban area. According to Blossom (2013), the majority of the families in Kerala spent up to 10 per cent of their total food expenditure for the purchase of cereals of which the major portion is rice. Vidya (2016) reported that tribal families used rice every day.

2.2 Nutritional and health benefits of red rice

Varieties of rice used in India, vary according to climate and terrestrial conditions. Rice characterised by the presence of a red bran layer, called red rice were prevalent in the south, east and the hilly tracts of the Northeast and West

India (Saxena, 2014). Coloured rice has been preferred in the past for their special features such as medicinal value and exclusive taste.

The commonly used red rice varieties in Kerala are *Uma, Jyothi, Kumbhan, Karuna, Harsha, Deepthi, Makaram, Kanchana, Aathira and Aiswarya*. *Red matta*, a rice variety which retains its pink hue even after bran is removed and is delicate with characteristic flavour when cooked (Lathadevi *et al.*, 2007). Red *matta* rice is the most used rice variety in Kerala and is also known as Kerala *matta* rice. *Matta* rice was believed to be the royal food consumed during the *Chera-Chola* period. The peculiarity of this rice is its red pericarp and it ensures high content of nutrients. *Njavara* rice is a medicinal red rice variety and it is used exclusively in traditional ayurvedic preparations. *Njavara* is a type of medicinal rice cultivated in Kerala (Deepa *et al.*, 2008).

Nandini (1995) assessed calorific value of 17 rice varieties of Kerala and reported that traditional varieties of rice gave higher values for calories. The highest value of 358 Kcal was noticed in traditional variety *Thekkancheera*. Sugeetha (2010) evaluated the starch content of eight varieties of KAU and found the highest starch content of 76.25 per cent in MO8-20-KR variety. A starch content of 75.13 per cent and 79.61 per cent was observed in parboiled and raw rice of *Jyothi* variety (Lakshmi, 2011 and Sathyan, 2012).

According to Nandini (1995) hybrid derivatives were found to have higher protein content when compared to traditional rice varieties. The highest protein content was observed in *Remya* (10.75g) hybrid derivative while the lowest value was for *Aryan* (7.01g) traditional variety. Dehusked *Njavara* rice consisted of 73 per cent carbohydrates, 9.5 per cent of protein and 2.5 per cent of fat (Deepa *et al.*, 2008). Sugeetha (2010) reported that OM-2 obtained the highest protein content of 8.17g/100 among different Kerala rice varieties. According to Sathyan (2012) a protein content of 8.11 per cent was observed in *Jyothi* rice variety. Thomas *et al.* (2013) observed protein content of 8.16 per cent in black rice varieties. According to Chandhni (2015) protein content of 8.75g, 8.95g, 7.5g,

7.0g, 8.1g in various varieties like *Ezhome-1*, *Ezhome-2, Prathyasha, Vyttila-8* and *Vaishak* respectively.

Sugimoto *et al.* (1998) evaluated the lipid content of six varieties of brown rice and and it ranged from 2.1 to 3.2 g/100g. Yadav and Jindal (2007) reported a fat content in the range of 0.54 to 0.82 in Indian rice cultivars.

About 50 g of brown rice provides about 35 per cent of the recommended dietary allowance of selenium, copper, zinc and manganese per day (Pengkumsri *et al.*, 2015). According to Chandhni (2015) iron content in red rice varieties were 0.41mg, 0.51mg, 0.61mg, 0.44mg and 0.47mg in *Ezhome-1, Ezhome-2, Prathyasha, Vyttila-8* and *Vaishak* respectively. Selvarajan *et al.* (2016) reported that brown rice is rich in minerals like magnesium, phosphorus, manganese and selenium. *Samba* rice is cultivated mainly in Sri Lanka and some parts of India like Tamil Nadu. *Samba* rice fills the stomach in minimal quantity and thereby decreases the calorific value. It is rich in amino acids so it helps to improve muscle growth.

The highest calcium content for raw rice was noticed in hybrid derivative *Vyttila-3* (11.25 mg/100g) while the lowest calcium content was recorded for hybrid derivative *Bhadra* (9.80mg/100g) (Nandini, 1995). Deepa *et al.* (2008) reported a higher phosphorus content of 324mg/100g in *Jyothi* rice variety. Chandhni (2015) observed a phosphorus content of 128.17mg, 135.41mg, 122.87mg, 95.87mg and 90.29mg in varieties *Ezhome-1, Ezhome-2*, *Prathyasha, Vyttila-8* and *Vaishak* respectively.

An iron content of 3.42 mg/100g was found in the variety *Hraswa* and lowest value of 2.52 mg/100g was found in traditional variety *Aryan* (Nandini, 1995). *Njavara* rice contains 1.93 mg of iron, 11.6 mg of calcium, 30.9 mg of sodium, 216 mg of magnesium, 304 mg of potassium and 354 mg of phosphorus (Deepa *et al.,* 2008). *Sonamasuri* is a rice variety which is grown in Kerala, Karnataka, Andhra Pradesh and West Bengal. It is having low sodium and low fat contents. According to Chandhni (2015) the amount of thiamine in various

varieties are 0.06 mg in *Ezhome-1*, 0.06mg in *Ezhome-2*, 0.03mg in *Prathyasha*, 0.02 mg in *Vyttila-8* and 0.07 mg in *Vaishak*.

Sugeetha (2010) found that a highest fibre content of 0.29 per cent in MO-95-1 variety. Brown rice contains higher proportions of dietary fibre compared to fully polished white rice. Parboiled *Jyothi* variety contains 0.72 g of fibre (Lakshmi, 2011). Chandhini (2015) reported that the fibre content of 0.7g/100g, 0.64g, 0.35g, 0.26g, 0.18g, 0.2g, 0.08 was noticed in *Ezhome-1, Ezhome-2, Prathyasha, Vyttila-8, Jyothi, Uma* and *Vaishak* respectively.

Varietal differences accounts for the variability in quality characteristics and also on health benefits. Zhang (2005) reported that coloured rice varieties have antioxidant properties and are more nutritious and rich in minerals. According to Itani and Ogawa (2004), red rice is considered as functional food because of its high polyphenols and anthocyanin content. The antioxidants present in black rice are essential for memory enhancement and strengthening of the immune system (Choi *et al.*, 2007). In Ayurveda, red rice is highly valued due to its power in redressing the balance in the '*tridosha*', the basic principle governing metabolism of the body (Ahuja *et al.,* 2007). In Himachal Pradesh red rice is consumed to cure blood pressure and fever (Saxena, 2014). The author also reported that red rice reduces cholesterol and total triglycerides. Red rice is used in Uttar Pradesh for treating leucorrhoea and abortion complications. In Karnataka, it is preferred for coolness and as tonic (Chaudhary and Tran, 2001).

Red and black rice varieties contain the pigment anthocyanins which have medicinal properties like anti-oxidant, anti-inflammatory and anticarcinogenic effects. Because of these properties they are considered as functional foods. The antioxidant and scavenging activity of red rice is higher than that of white rice. Red rice is good for diabetic patients due to their low glycaemic index, which helps in preventing cancer and obesity (Bhat and Riar, 2015). Brown rice is good for losing weight because it provides satiety and stays in our stomach for a long time compared to white rice. Vethavarshini *et al.* (2013) reported that eating one

bowl of brown rice helps to provide fullness. Fibre present in brown rice moves fat through our digestive system faster so that its absorption will be less and thereby controls blood sugar level (Vethavarshini *et al.,* 2013).

Dehusked *Njavara* rice contain high amount of protein, fibre, minerals and vitamins (Deepa *et al.,* 2008). Reshmi (2012) indicated the presence of a gene fragment encoding a protein in *Njavara* which is reported to have anti-carcinogenic property, especially against breast cancer. *Njavara* is mostly used in Ayurveda for treating muscloskeletal disorders (Selvarajan *et al.,* 2016).

Brown rice can substantially reduce the risk of colon cancer, as it is a very good source of selenium, a trace mineral that induces DNA repair and synthesis in damaged cells and inhibits the proliferation of cancer cells (Vethavarshini *et al.*, 2013). Brown aromatic basmati rice contains 20 per cent more fibre than other brown rice varieties, which prevents the formation of cancerous cells in the body (Bhat and Riar, 2015). Brown rice have high amount of magnesium and fibre and it provides relief from constipation because they help to normalise bowel function.

Brown rice has low glycaemic index than white rice and contains γ-aminobutyric acid (GABA) and dietary fibre. GABA potentiate the insulin secretion in pancreas so it is more suitable for diabetic patients (Seki *et al.*, 2005). *Rakthasali* is a traditional red rice variety which is best for skin, eyesight, diuretic and improve voice and fertility (Deepa *et al.,* 2008). Hedge *et al.* (2013) noticed that partially boiled red raw rice was specifically used during lactation. *Red matta* rice decreases the incidence of diabetes mellitus (Selvarajan *et al.,* 2016).

Colored rice have been found to reduce atherosclerotic plaque by 50 per cent more than white rice (Zhang, 2005). Brown rice helps to raise blood levels of nitric oxides which is known to improve blood vessel dilation thereby preventing the formation of atherosclerotic plaques (Panlasigui and Thompson, 2006). Whole grain decrease the risk of cancers of the upper gut and colorectal cancer risk reduction from 35 per cent to 50 per cent (Wakai *et al.,* 2006). Brown rice has antioxidants and phytonutrients that boosts the immune system, lowers

cholesterol, reduce the risk of heart disease, stroke, colon cancer and reduces severity of asthma (Vethavarshini *et al.,* 2013).

Mohan *et al.* (2014) reported that brown rice is rich in phytochemicals such as polyphenols, oryzanol, phytosterols, tocotrienols, tocopherols and carotenoids as well as vitamins and minerals that have a protective effect against heart disease and cancer.

Traditional scented rice varieties have been revealed to possess higher amount of iron and zinc. According to Zhang *et al.* (2005) coloured rice varieties possess antioxidant properties and are rich in iron, zinc and other minerals.

2.3. Effect of parboiling on rice grain quality

Parboiling is believed to be originated around more than 1000 years ago. Bhattacharya (1972) reported that about one-fifth of the world's rice is parboiled. Parboiling is a hydrothermic treatment given to rough rice, and consists of soaking, steaming and drying (Islam *et al.,* 2002). Parboiling is the hydrothermal treatment of paddy before milling and it includes soaking, steaming and drying. The primary objective of parboiling is to improve the quality of rice and obtain a higher milling yield (Oyedele and Adeoti, 2013).

NARI (2003) reported that parboiling is a method used to partially cook the paddy rice. Saif *et al.* (2006) reported several advantages for parboiled rice such as increase in length, width and thickness the strengthening of kernel integrity, increase of milling recovery and decrease of cooking losses. Parboiling is a processing technique which involves, soaking, steaming and drying of paddy. Advantages of parboiling over a raw milled rice are a better recovery during milling, increasing hardness of grain, resistance to breakage, inactivation of enzymes, biological sanitation, easier removal of hull during milling, better grain swelling during cooking, less starch leaching in the cooking water and desirable changes in texture and taste of rice (Sujatha *et al.,* 2004).

Miah *et al.* (2002) reported that paddy soaked for 30 minutes and steamed under 123.60 KPa pressure for 22 minutes gives maximum rice yield. Bhattacharya (2004) reported that the milling quality of parboiled rice is strongly dependent on the conditions of its drying. According to Siebenmorgen and Cooper (2005), the maximum head rice yield could be achieved when the rice starch is 40 per cent gelatinised during parboiling. Parboiling process provide higher head rice yield as compared to raw rice (Sareepuang *et al.,* 2008). Parnsakhorn and Noomhorn (2008) stated that increase in head rice yield after parboiling process is observed because of increased tensile strength of the kernel caused by gelatinisation of the starch granules. According to George (2012) the most advantageous aspect of parboiling is the increase in the head rice yield.

Parboiled rice cooks more flaky than raw rice and loss of solids into gruel is also less. Adeyami *et al.* (1986) reported that parboiled rice has longer cooking time due to the strong cohesion between the endosperm cells which are tightly packed. Islam *et al.* (2001) and Ayamdoo *et al.* (2014) reported that parboiling process resulted in higher cooking time. Parboiled rice needs more time to cook because of the hardness attained after parboiling.

According to Mustapha (1979) parboiled rice has higher water absorption, which may be due to the steaming pressure during parboiling which in turn affects starch gelatinization. Severe parboiling upto 36 h soaking combined with 90 min steaming gave rice with less water uptake when compared to medium parboiled rice. The medium parboiled rice expanded more than the severe parboiled rice, as they were well gelatinized absorbing more water during cooking (Ayamdoo *et al.,* 2014).

According to Gariboldi (1974) amylose content is less in parboiled samples than non- parboiled samples because of the starch solubilisation and leaching of the amylose molecules into the surrounding water during soaking and subsequent steaming during parboiling. Sang *et al.* (2008) reported that amylose inhibits swelling of starch granules by forming complexes with lipids, which

results in a lower peak viscosity at higher pasting temperatures. Bellousi *et al.* (2010) stated that the gel consistency was lower in parboiled rice. According to Mir and Bosco (2013) parboiling was observed to decrease the pasting profile of rice and increases the water solubility of rice.

The temperature and period of soaking and steaming significantly influence whiteness of parboiled rice. Rapid cooling of the steamed paddy is necessary if soft cooking quality and desired colour is required because slow cooling would produce harder rice with much darker colour (Bhattacharya, 1972). Islam *et al.* (2003) reported that due to parboiling treatment, discoloration of grain occurs which decreases the lightness value. The lightness of parboiled rice was mainly affected by the temperature and time of steaming.

The carbohydrate content of the parboiled rice samples was higher than that of the nonparboiled samples. Starch reassociation, increase in some carbohydrate components like reducing sugars, change in molecular size and partial dextrinisation of starch was found to occur during parboiling (Rhaghavendra and Juliano, 1970). According to Sugeetha (2010) the variety MO8-20-KR contains 76.25 per cent of starch. According to Lakshmi (2011) parboiled *Jyothi* variety contain a 75.13 per cent of starch in parboiled rice.

Otegbayo *et al.* (2001) reported that there is decrease in protein content of the parboiled rice samples compared to the nonparboiled samples which may be due to leaching of protein substances during soaking and rupturing that occurs due to steaming. Patindol *et al.* (2008) reported that parboiling sparingly changed protein content. Sugeetha (2010) reported that parboiled variety OM-2 contain 8.17g of protein. Lakshmi (2011) observed that protein content in *Jyothi* variety ranges between 5.26 to 7.55 per cent. Parboiled Asian varieties contain 5.00-6.69 per cent of protein.

Sareepuang *et al.* (2008) also reported significant increase in crude fat, crude protein and crude fibre after parboiling at 50°C. According to Lakshmi (2011) the lipid content in parboiled *Jyothi* variety varied from 0.23 to 1.30 per

cent. The parboiled rice has less lipid content compared to raw rice because the oil content in embryo diffuses out of the grain during the steaming process (Joseph *et al.*, 2011). Akther *et al.* (2015) reported that the loss of crude fat in parboiled samples may be due to the heating process and leaching of fat into the soaking water.

Parboiled brown rice variety contains 1.72 per cent of fibre (Sareepuang *et al.,* 2008). Sugeetha (2010) reported a crude fibre content of 0.44 per cent in parboiled MO8-20-KR variety. Parboiled *Jyothi* variety contains 0.72 g of fibre (Lakshmi, 2011). According to Akther *et al.* (2015) crude fibre content of parboiled rice ranges between 0.37-0.49 per cent.

Juliano *et al.* (1985) reported that parboiled brown rice contain less thiamine content. Loss of thiamine may be due to leaching into the treatment water or to thermal degradation of thiamine in water. According to Otegbayo *et al.* (2004) parboiled brown rice contains 0.021 mg of thiamine. Lakshmi (2011) observed a thiamine content of 0.24mg in parboiled *Jyothi* variety and 0.203mg in parboiled milled rice (Marie *et al.*, 2016). Akther *et al.* (2015) reported that parboiled rice contain vitamin B6 ranging between 1.02 to 13.17 ppm.

Parboiled brown rice contains 0.9 per cent of ash (Otegbayo *et al.,* 2004). Sugeetha (2010) reported that parboiled MO8-20-KR variety contains 0.93 % of ash. Iron content in parboiled varieties ranged between 1.50 to 2.30 mg (Sugeetha, 2010). The author stated that the calcium content in parboiled rice varieties varies between 11.20 to 13.50 mg. Mild parboiling resulted in parboiled rice with high ash content (Joseph *et al.,* 2011). Lakshmi (2011) observed 5.94 mg of calcium, 161.83 mg of phosphorus and 0.18 mg of iron in parboiled *Jyothi* variety. The composition of ash, phosphorous, calcium, iron, manganese, molybdenum and chromium was found to be higher in milled parboiled rice than in the raw rice (Ejebe *et al.,* 2013). According to Ayamdoo *et al.* (2015) parboiled Jasmine-85 rice variety contains 1.6 mg of iron, 0.90 mg of zinc and 2.5 mg of calcium.

Calcium content of 5.38 mg and ash content of 1 g was observed in parboiled milled rice (Marie *et al.*, 2016).

According to Parnsakhorn and Noomhorn (2008) the highest organoleptic score was observed in parboiled brown rice than milled brown rice. Sene *et al.* (2017) observed that cooked parboiled rice is more digestible, because of its texture and firm consistency. In addition, after cooking the grains are firmer and less prone to sticking.

Basmati rice contains more aroma than the traditionally cultivated scented rice varieties (Nadaf *et al.*, 2006). Lamberts *et al.* (2008) observed that parboiled rice has better organoleptic qualities. The parboiling treatment helps in retaining some of the nutrients. Bhonsle (2010) observed excellent over all acceptability in Indian varieties like *Basmati local, Jiresal, Kotimirsal, Pusa Basmati-1, Pusa Sugandh-2, Pusa Sugandh-3, Kasturi* and *Vasumati.*

Chitra *et al.* (2009) observed a higher digestibility in parboiled rice than normal rice. Laokuldilok and Rattanathanam (2014) stated that parboiling increases the bran oil content and it does not need any stabilization to reduce lipase activity because the paddy itself treated with steam during parboiling.

2.4. Rice based value added products

Rice is a cereal consumed by great part of the human population throughout the world in the kind of many products, such as white rice, parboiled rice, processed rice products, rice bran etc. Rice is generally consumed in the form of cooked table rice and in some other modified form. Once milled, rice can be stored without refrigeration for over one year. For these reasons, rice is generally considered as an easy food. In response to new consumer needs, processing of raw rice into new products has been undertaken with the development of instant rice (Roy *et al.*, 2008).

Several convenient rice products have been introduced such as instant rice, personal portions in easy pouches and microwave rice etc. Rice is also a common

ingredient for ready-made meals and product mixes (USAID, 2012). Other examples of rice based value added products include rice flour and starch, cakes and puddings, baked bread and crackers, breakfast cereals, rice snacks and noodles, baby or weaning foods, rice milk, fermented foods and beverages and bran products (Chumniwkri and Peuchkamut, 2016).

According to Mongkontanawat and Lertnimitmongkol (2015) the rice-based foods have also been diversified with various convenient products, like frozen cooked rice, retort pouched cooked rice and aseptic cooked rice.

Puffed rice is very popular in many countries as a cereal breakfast component or as a light food. It is a whole grain puffed product from parboiled milled rice (Sharma, 2012). Convenient snack foods like popped and puffed rice are very popular not only in Indian continent, but also worldwide (Jaybhaye *et al.,* 2014). Puffed rice is very popular in many countries as cereal breakfast component or as a light food. It is a whole grain puffed product from parboiled milled rice. It is prepared from hydrothermally treated or pre-gelatinized milled rice by heating in high temperature air, oil and sand or by gun puffing method. Puffed rice is ready for consumption and easily digestible. It is commonly used in snacks, cereal drinks, Ready-to-Eat (RTE) breakfast cereals and infant foods (Mishra *et al.,* 2014).

Flaked rice is a major product in India. It is known by a number of names, including *aval* (Tamil), *avalakki* (Kannada), *atukulu* (Telugu) and *poha* (Hindi). The process involved in the production of flaked rice are cold or hot soaking, roasting, flaking, sieving and packing. In flaked rice production, generally freshly harvested paddy is preferred as it gives more whiteness (Sulochana *et al.*, 2007).

Rice noodles are traditionally prepared popular dish, broadly consumed in most of the South-East Asian countries (Fiedler *et al.*, 2009). Rice noodles have a very smooth texture, soft mouth feel and are white in colour (Thomas *et al.,* 2014).

Bean and Nishita (2000) developed successfully baked rice products for those suffering from celiac disease. *Hurum* is an expanded rice product made from waxy rice. Steps involved in preparation are soaking of paddy, parboiling, dehusking of paddy at high moisture, immediate flaking, rubbing of fat to the flaked rice and expansion in sand (Mishra *et al.*, 2014).

Edible rice papers are made from wet-milled high amylose rice batter in East and South East Asia. It is translucent and is used as edible candy wrappers. Expanded rice is prepared by heat expansion of milled parboiled rice taking advantage of the property of cooked starch to expand when heated where by the product retains the shape of milled rice. Expanded rice is used in many forms as breakfast dishes or snacks (Esa *et al.*, 2013).

Idli, one of the most common traditional cereal-pulse based fermented breakfast product is consumed mostly in the southern part of India and Srilanka. It is the most preferred breakfast product due to its soft texture, mild pleasant flavour and aroma, easy digestibility and known health and nutritional benefits. *Idli* being a lactic acid bacteria fermented product, is traditionally prepared by rice and dhal soaked, ground and fermented before steamed and consumed (Nisha *et al.*, 2005).

Dupart *et al.* (1999) developed a process for the manufacture of reconstitutable rice grains by cooking a mixture of rice flour, water and hydrogenated oil in a cooker-extruder. Instant rice, quick cooking rice etc are the novel rice products formulated according to the new consumer needs.

Medium grain low amylose rice is used in making baby foods and breakfast cereals. Rice starch is used as thickening agent in food preparation including infant formula. The granular size of rice starch is relatively small. Intermediate amylose (20-25 per cent) varieties are used mainly for fermented cakes and in making canned soups. High amylose rice (>25 per cent) is used for extruded rice noodles (Cheowtirakul, 2001). Rice crackers, one of the traditional

rice products in Japan and other Asian countries, are palatable, low in calorie and can be preserved for a long time (Nakamura *et al.*, 2012).

Rice husks are being transformed in many non-food applications such as fertilizer, incubation materials, paper, hair and skin care products. Good quality bran from parboiling mills is currently sold to poultry operations. Bran which contains 16 per cent oil can also be processed in solvent extraction plants to yield edible oil. Rice bran is used in cattle and poultry feed, defatted bran which is rich in protein, can be used in the preparation of biscuits and as cattle feed. Rice bran wax, a by-product of rice bran oil is used in industries (Ahiduzzaman and Islam, 2009). Rice bran oil is considered as richest oil sources among the grain by-products and has a desirable fatty acid profile with 35 per cent linoleic acid and 2 per cent linolenic acid (Sharma *et al.*, 2014).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study entitled Quality evaluation of KAU red rice (*Oryza sativa* L) varieties was carried out with the objective to assess the effect of parboiling on the physical, biochemical, nutritional, cooking and organoleptic qualities of KAU red rice varieties. The study was also aimed to assess the suitability of these rice varieties for the preparation of selected traditional food products.

The materials used and the methods followed in the present study are given under the following headings.

3.1 Collection of rice varieties

3.2 Parboiling of rice varieties and preparation of rice flour

3.3 Quality evaluation of rice varieties

3.4 Organoleptic evaluation of traditional food products with rice and rice flour

3.4.1 Organoleptic evaluation of table rice

3.4.2 Preparation of traditional products

3.5 Statistical analysis

3.1 Collection of rice varieties

The high yielding rice varieties released by Kerala Agricultural University namely *Kanchana* (PTB 50), *Aiswarya* (PTB 52), *Aathira* (PTB 51), *Samyuktha* (PTB 59) and *Ezhome-4* were collected from Regional Agricultural Research Station, Pattambi and Regional Agricultural Research Station, Pilicode. Commonly used red rice variety *Jyothi* was kept as the control and was collected from Agricultural Research Station, Mannuthy. The collected rice varieties are shown in plate 1a and 1b.

Aathira (PTB 51) is a medium duration high yielding rice variety. It is best suited for the first and second crop seasons of Wayanad. It produces red, short

Jyothi

Aathira

Aiswarya

Ezhome-4

Kanchana

Samyuktha

Plate 1. Rice varieties selected for the study

bold grains with good cooking quality. *Aiswarya* (PTB 52) is long, bold grains and suited for first and second crop seasons. *Kanchana* (PTB 50) is red, long, bold grains and suited for all seasons and is also suitable for *kole* and *kuttanad* regions. *Ezhome-4* is a high yielding, non-lodging red rice variety. It is designed for the saline- prone kaipad rice fields of Kerala. It was released as variety for cultivation in *koottumundakan* system during 2010. *Samyuktha* (PTB 59) is short, bold red kernel.

3.2 Parboiling of rice varieties and preparation of rice flour

The selected paddy samples were parboiled by the hot soaking process developed by CFTRI (1969). Paddy was soaked in water at 60-75°c for three to four hours. Water was drained and soaked paddy was steamed in the same vessel for 5-10 minutes and was sundried until a moisture content of 13 % is obtained.

The milled rice was washed and removed excess water and dried in sunlight and powdered using a commercial pulveriser. The rice flour was roasted and used for the preparation of traditional product *idiyappam.*

3.3 Quality evaluation of rice varieties

Various quality parameters like physical qualities, cooking qualities, biochemical and nutritional qualities were assessed.

3.3.1 Physical qualities of rice

Paddy having moisture content of less than 13 per cent was dehulled with a laboratory sheller (RETC drier manufactured by ENGART Engineering Services Maharashtra, model no: NF 268). Weighed quantity of paddy was poured into the hopper for dehulling. The resulting brown rice was weighed to obtain the per cent of hull and brown rice (Khush *et al.,* 1979). The brown rice was again milled in a laboratory polisher (Mac Lawkin (Godrej.com) Jupiter Scientific Company, Tamilnadu Model No: LK 1140) for 30 seconds with the prescribed added weight (100g) on the pressure cover, followed by a second milling for another 30 seconds without the weight. The fraction removed in the first milling

was considered as bran and that after the second milling, as polish. The milled rice sample was collected in a thick paper bag and sealed immediately. The rice was allowed to cool before weighing. This procedure minimises grain cracking during cooling (Adair, 1952). The data obtained from milling of paddy was used for determining the physical qualities like milling per cent, head rice recovery, thousand grain weight, volume weight, grain shape and grain size.

3.3.1.1 Milling per cent

Milling per cent includes the weight of head rice and broken rice and is calculated as follows.

$$\text{Milled rice (\%)} = \frac{\text{Weight of milled rice}}{\text{Weight of paddy}} \times 100$$

3.3.1.2 Head rice recovery

Whole grains (head rice) were separated from the milled rice with a winnower. The resulting head rice was weighed to get head rice recovery (Adair, 1952).

$$\text{Head rice recovery} = \frac{\text{Weight of head rice}}{\text{Weight of paddy}} \times 100$$

3.3.1.3 Thousand grain weight

This was measured by the method of Redding *et al.* (1991). It involved the counting and weighing of 1000 randomly selected unpolished brown rice kernels.

3.3.1.4 Volume weight

Volume weight was measured as described by Ali *et al.* (1993). A 500 ml graduated cylinder was filled with a known amount of water (100ml). Thousand grains of milled rice kernels were dropped into the cylinder. Tapped the cylinder to remove any air bubbles attached to the grains and recorded the total volume

(rice + water). From this, the initial volume of water is subtracted to get the volume of rice and is expressed as mm^3.

3.3.1.5 Grain shape and grain size

Grain appearance depend upon the size and shape of the kernel. Length and width of grain were measured using grain vernier and using the following scale, grain size and shape was determined. For size: extra-long, >7.50 mm; long, 6.61 to 7.50 mm; medium, 5.51 to 6.60 mm and short, <5.50 mm was used. For shape, based on length-to-width ratio grain was classified as detailed below.

Slender >3.0
Medium 2.1 to 3.0
Bold 1.1 to 2.0
Round <1.0 (IRRI, 2002)

3.3.2 Physical qualities of rice flour

Rice samples were washed and strained to remove excess water and powdered. The following physical qualities of rice flour were studied.

3.3.2.1 Bulk density

The bulk density of rice flour was determined by the method suggested by Okaka and Potter (1977). Fifty gram sample was put into a 100 ml graduated cylinder. The cylinder was tapped 50 times and bulk density was calculated as weight per unit volume of sample.

3.3.2.2 Water absorption index (WAI) and water solubility index (WSI)

WAI and WSI of flour were determined by the method of Anderson *et al.* (1969). The ground flour sample (2.5g) was mixed with 30 ml distilled water using a glass rod and cooked at 90°C for 15 minutes in a water bath. The cooked paste was cooled to room temperature and transferred to centrifuge tubes and centrifuged for 10 minutes. WAI and WSI were calculated by the expressions.

$$WAI = \frac{\text{Weight of sediment}}{\text{Weight of the dry solids}}$$

$$WSI = \frac{\text{Weight of the dissolved solids in supernatant}}{\text{Weight of the dry solids}}$$

3.3.2.3 Retrogradation property

Retrogradation property was evaluated by the method described by Singh *et al.* (2005). Flour paste (9%) was heated to 90°C for 20 minutes and then cooled. These cooked rice flour paste was stored for 3, 6, 9, 12 days at 4°C. Syneresis was measured as percentage amount of water released after centrifugation in 15 minutes.

3.3.3 Cooking qualities of raw and parboiled rice

Cooking and eating characteristics of rice are largely determined by the properties of the starch that makes up 90 per cent of milled rice. Hence, cooking qualities of milled rice were evaluated. Rice varieties were cooked by straining method suggested by Saleh and Meullener (2007). Rice was measured and washed with cold water, strained and repeated washing. Put a fairly large quantity of water in a big pan and bring to the boil. Add the rice into the boiling water. After cooking, rice water was drained.

3.3.3.1 Gelatinisation temperature index

An estimate of the gelatinisation temperature was indexed by the alkali digestion test suggested by Little *et al.* (1958). It is measured by observing the degree of spreading individual milled rice kernels in a weak alkali solution (1.7% KOH). Six whole-milled kernels without cracks were selected and placed in a petridish. Ten ml of 1.7 per cent potassium hydroxide (KOH) solution was added. The samples were arranged to provide enough space between kernels to allow for spreading. The petridishes were covered and incubated for 23 hours at 30°C in an

oven. Starchy endosperm was rated visually to index the degree of spreading in alkali.

Rice with a low gelatinisation temperature disintegrates completely whereas rice with an intermediate gelatinisation temperature shows only partial disintegration. Rice with a high gelatinisation temperature remains largely unaffected in the alkali solution.

3.3.3.2 Cooking time

Optimum cooking time was estimated by the method outlined by Juliano and Bechtel (1985). In a 250 ml beaker, about 100 ml distilled water was boiled (98 ± 1°C) and 10g of head rice sample was dropped into it. Measurement of cooking duration was started immediately. After 10 minutes and every minutes thereafter, one or two grains of rice were removed and pressed between two clean glass plates. Cooking time was recorded when at least 90 per cent of the grains no longer had opaque core or uncooked centres. The rice was then allowed to simmer for about another two minutes to ensure that the core of all grains had been gelatinised. Optimum cooking time included the additional two minutes of simmering.

3.3.3.3 Water uptake

Water uptake was estimated by the method suggested by Zhou *et al.* (2007). A known weight of milled rice grains (10g) was cooked with excess cooking water (100 ml) in a beaker. The excess residual cooking water was withdrawn using a pipette after the cooking process and the volume was measured. Water uptake capacity of the cooked rice grain was calculated from the difference between the total cooking water and residual cooking water after the cooking process and expressed as milli litre per gram of grain.

Water uptake = Total cooking water – Residual cooking water

3.3.3.4 Volume expansion

Volume expansion was estimated by the method described by Pillaiyar and Mohandas (1981). It was determined from the ratio between the cooked volume of rice to that of uncooked rice. The volume of the 10 milled kernels was noted initially and after cooking in a graduated test tube. The volume expansion is calculated from the ratio between cooked volume to the uncooked volume.

$$\text{Volume expansion} = \frac{\text{Cooked volume}}{\text{Uncooked volume}}$$

3.3.3.5 Amylose content

Amylose content was determined by the method suggested by Sadasivam and Manikkam (1992). To 100 mg of powdered rice sample, one ml of 1 N NaOH were added and kept overnight and and the volume was made up to 100 ml. The extract (2.5 ml) was taken and added about 20 ml of distilled water and three drops of phenolphthalein. Then 0.1 N HCl was added drop by drop until the pink colour disappears. To this, one ml of iodine reagent was added and the volume was made up to 50 ml. The intensity of the colour developed was read at 590 nm in spectrophotometer. The amylose present in the sample was estimated from standard graph prepared using serial dilution of standard amylose solution and expressed in percentage.

3.3.3.6 Gel consistency

Gel consistency was measured by the method suggested by Cagampang *et al.,* (1973). All the rice samples for measuring gel consistency were stored in the same room for 2 days so as to equalize the moisture content of the grain. Whole milled rice grains were ground to give a fine flour (100 mesh). Hundred milligram of the powder was weighed into test tubes. Ethyl alcohol (0.2 ml of 95 per cent) and 2.0 ml of 0.2 M KOH were added with a pipette. The contents were mixed well. The test tubes were covered with glass marbles (to prevent steam loss and to reflux the samples). The samples were cooked in a vigorously boiling water bath for eight minutes, until the tube contents reached the 2/3 height of the tube. The

test tubes were removed from the water bath and left to stand at room temperature for five minutes. The tubes were cooled in an ice-water bath for 20 minutes and laid horizontally on a laboratory table, lined with a graph paper. The total length of the gel was measured in millimetre from the bottom of the tube to the gel front.

Gel consistency of rice varieties were classified as

Soft	> 61-100
Medium	41-60
Medium hard	36-40
Hard	< 26-35

3.3.3.7 Grain elongation

The method by suggested by Azeez and Shafi (1966) was followed for evaluating the degree of elongation of cooked rice grains. The elongation test consists of taking 25 whole milled kernels in a beaker that were soaked in 20 ml of distilled water for 30 minutes. The samples were placed in a water bath and the temperature was maintained at 98°C for 10 minutes. The cooked rice was transferred to a petridish lined with filter paper. Ten cooked whole grains were selected and measured by placing it linearly on a graph paper. The proportionate elongation was the ratio of the average length of cooked rice grains to the average length of raw rice grains.

3.3.4 Nutritional qualities of rice

Biochemical and nutritional qualities of milled rice were assessed using standard procedures. Analysis was carried out in triplicate samples for the following constituents.

3.3.4.1 Moisture

Moisture content of rice was estimated by the method of A.O.A.C (1980). To determine the moisture content, five gram of rice was taken in a petridish and

dried in a hot air oven at 60°C-70°C, cooled in a desiccator and weighed. The process of heating and cooling was repeated until a constant weight was achieved. The moisture content was calculated from the loss in weight during drying and expressed in percentage.

3.3.4.2 Starch

The starch content was estimated colorimetrically using anthrone reagent (A.O.A.C, 1980). The rice grains were powdered and the rice powder (0.5g) was extracted with 80 per cent ethanol to remove sugars. Residue was repeatedly extracted with hot 80 per cent ethanol to remove sugars completely. The residue was dried over a water bath and 5 ml of water and 6.5 ml of 52 per cent perchloric acid were added and extracted at 0°C for 20 minutes. The supernatant was cooled and made up to 100 ml. Pipetted out 0.2 ml of the supernatant and made up to 1 ml with water and 4 ml of anthrone reagent was added, heated for eight minutes, cooled and read the OD at 630 nm in a spectrophotometer.

A standard graph was prepared using serial dilution of standard glucose solution. From the graph, glucose content of the sample was obtained and multiplied by a factor of 0.9 to arrive the starch content.

3.3.4.3 Protein

Protein content was estimated by the method of A.O.A.C (1980). Rice (0.2g) was digested with 6 ml Con. H_2SO_4 after adding 0.4 g of $CuSO_4$ and 3.5 g K_2SO_4 in a digestion flask until the colour of the sample was converted to green. After digestion, it was diluted with water and 25 ml of 40 per cent NaOH was pumped. The distillate was collected in 20 per cent boric acid containing mixed indicator and then titrated with 0.2 N HCl, to determine the nitrogen content. The nitrogen content obtained was multiplied with a factor of 6.25 to get the protein content and expressed in per cent.

3.3.4.4 Fat

Fat content of rice was estimated by the method of A.O.A.C. (1955). Five gram of rice was powdered and taken in a thimble and plugged with cotton. The material was extracted with petroleum ether for six hours without interruption by gentle heating in a soxhelt apparatus. Extraction flask was then cooled and ether was removed by heating and weight was taken. The fat content was expressed in per cent.

3.3.4.5 Crude fibre

Crude fibre was estimated by acid alkali digestion method as suggested by Chopra and Kanwar (1978). Two gram of rice was powdered and boiled with 200 ml of 1.25 per cent sulphuric acid for 30 minutes. It was filtered through a muslin cloth and washed with boiling water and again boiled with 200 ml of 1.25 per cent sodium hydroxide for 30 minutes. Again, it was filtered through a muslin cloth and washed with sulphuric acid, water and alcohol. The residue was transferred to a pre weighed ashing dish, dried, cooled and weighed. The residue was then ignited for 30 minutes in a muffle furnace at 600°C, cooled in a dessicator and reweighed. The fibre content of the sample was calculated from the loss in weight on ignition and expressed in per cent.

3.3.4.6 Thiamine

Thiamine content was estimated by the method suggested by Sadasivam and Manikam (1992). Five gram of sample was finely ground and taken in a 250 ml conical flask. Slowly added 100 ml of 0.1 N sulphuric acid without shaking and kept overnight. After shaking vigorously, filtered through Whatman No.1 filter paper and discarded the first 10-15 ml of the filtrate. Pipetted out 10 ml of the extract into 100 ml separating funnels. Pipetted out 10 ml of the working standard and added 3 ml of 15 per cent NaOH into each separating funnel immediately, followed by four drops (0.2 ml) of ferricyanide solution. After shaking gently for exactly 30 seconds, 15 ml of isobutanol was added rapidly from a quick delivery burette. Stopped immediately and shook vigourously for 60

seconds and allowed the layers to separate. Drained off the bottom layer carefully and added one spatula of sodium sulphate directly into the separating funnel, stoppered and swirled gently to clarify the extract. The clear extract was collected from the top into a clean dry test tube and read at an exitation wave length of 365 nm and emission wave length of 435 nm, exitation band pass and emission band pass of 10 nm and sensitivity set at the 500 v in a spectroflurometer. The thiamine content was expressed as mg per 100 g of the sample.

3.3.4.7 Calcium

Calcium content was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Elmer, 1982). The diacid was prepared by mixing 70 per cent perchloric acid in the ratio 9:4. Two gram of rice sample was digested in this diacid and the extract was made up to 100 ml. This solution was read directly in atomic absorption spectrophotometer. Calcium content was expressed in mg 100 g of the sample.

3.3.4.8 Zinc

The zinc content of the sample was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Elmer, 1982). The diacid solution was directly read in atomic absorption spectrophotometer to find the zinc content and expressed in mg per 100 g of sample.

3.3.4.9 Iron

Iron content of the sample was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Elmer, 1982). The diacid solution was directly read in atomic absorption spectrophotometer to find the iron content and expressed in mg per 100 g sample.

3.3.4.10 Phosphorus

The phosphorus content was analysed colorimetrically as suggested by Jackson (1973) which gives yellow colour with nitric acid vandate molybdate reagent. To 5 ml of pre-digested aliquot, 5 ml of nitric acid vandate molybdate reagent was added and made up to 50 ml with distilled water. After 10 minutes, the OD was read at 420 nm. The content of phosphorous present in the sample was estimated from the standard graph prepared using serial dilution of standard phosphorous solution and expressed in mg per 100 g.

3.3.4.11 Oil content in rice bran

Fat content of rice bran was estimated by the method of A.O.A.C (1955). Five gram of rice bran was taken in a thimble and plugged with cotton. The material was extracted with petroleum ether for six hours without interruption by gentle heating in a soxhelt apparatus. Extraction flask was then cooled and ether was removed by heating and weight was taken. The fat content was expressed in per cent.

3.3.4.12 *In vitro* digestibility of starch

Starch digestibility was estimated as suggested by Satterlee *et al.* (1979). One gram of the sample was powdered and gelatinised in 100 ml water and boiled for one hour and filtered. One ml of gelatinised solution was taken and 1 ml of the enzyme solution (saliva diluted with equal quantity of water) was added. The mixture was incubated at 37°C for 1-2 hours. The reaction was stopped by adding 1 ml of NaOH. Later, glucose was estimated by the method suggested by Somoygi (1952) and IVSD was computed.

3.4 Organoleptic evaluation of traditional products with rice and rice flour

3.4.1 Organoleptic evaluation of table rice

Organoleptic evaluation of table rice (raw and parboiled) was carried out by preparing cooked samples of rice. A series of organoleptic trials were carried

out using simple triangle test at laboratory level to select a panel of fifteen judges between the age group of 18 to 35 years as suggested by Jellenick (1985). Score card containing three quality attributes namely texture, taste, colour, flavour and appearance was prepared for the organoleptic evaluation. Each of the above mentioned qualities were assessed by a nine point hedonic scale. The evaluation was carried out in the morning time using score card by a selected panel of fifteen judges.

3.4.1.1 Selection of judges

A series of organoleptic trials were carried out using simple triangle test at laboratory level to select a panel of fifteen judges between the age group of 18 to 35 years as suggested by Jellenick, (1985).

3.4.1.2 Preparation of score card

Score card containing five quality attributes namely appearance, colour, flavour, texture and taste were prepared for the evaluation of the products. Each of the above mentioned qualities were assessed by a nine point hedonic scale. Overall acceptability was computed separately using the average of above mentioned five quality attributes. The score card prepared given in Appendix I.

3.4.2 Preparation of traditional products

Idli was prepared with raw and parboiled rice of selected varieties. *Idiyappam* was prepared with raw and parboiled rice flour of selected rice varieties. The product prepared with *Jyothi* rice variety were kept as control. The procedures adopted for preparation of *idli* and *idiyappam* are given in Appendix II. The organoleptic evaluation was carried out as mentioned in 3.4.1.1 and 3.4.1.2.

3.5 Statistical analysis

The observations recorded were tabulated and the data was analysed statistically using complete randomized design (CRD). The data on physical

qualities of different rice varieties were analysed statistically using DMRT. The scores of organoleptic evaluation were assessed by Kendall's coefficient of concordance (W).

RESULTS

4. RESULTS

The results of the study entitled 'Quality evaluation of KAU red rice (*Oryza sativa* L.) varieties' are presented under the following heads.

4.1. Quality evaluation of raw and parboiled rice

4.1.1. Physical qualities of raw rice and parboiled rice

4.1.2. Physical qualities of raw rice flour and parboiled rice flour

4.1.3. Cooking qualities of raw rice and parboiled rice

4.1.4. Chemical and nutritional qualities of raw rice and parboiled rice

4.2. Acceptability of traditional food products

4.2.1. Organoleptic evaluation of table rice

4.2.2. Organoleptic evaluation of rice based products

4.1. Quality evaluation of raw and parboiled rice

4.1.1. Physical qualities of raw rice and parboiled rice

Physical qualities like milling per cent, head rice recovery, thousand grain weight, volume weight, grain shape and size of rice varieties were evaluated and are presented in table 1a, table 1b and also in Table 2.

4.1.1.1. Milling per cent

The milling per cent of raw rice varieties varied from 62.76 per cent (*Aathira*) to 76 per cent (*Ezhome-4*). Milling per cent of *Ezhome-4* was on par with *Samyuktha* (72.21%) but significantly different from all other varieties including control variety *Jyothi* (65%). *Samyuktha* was found to be on par with *Ezhome-4* but distinctly differ from other varieties.

The milling per cent of parboiled rice varied from 67.66 (*Aiswarya*) to 77.33 (*Ezhome-4*). Milling per cent of *Ezhome-4* was on par with *Kanchana*

Table 1a. Physical qualities of raw and parboiled rice

Varieties	Milling per cent (%)		Relative difference (%)	Head rice recovery (%)		Relative difference (%)
	R	P		R	P	
Jyothi	65.00^{cd}	71.00^{bc}	$9.23^{(3)}$	52.46^{b}	53.66^{b}	$2.28^{(6)}$
Aathira	62.76^{d}	73.66^{ab}	$17.36^{(1)}$	57.90^{a}	61.40^{a}	$6.04^{(4)}$
Aiswarya	65.75^{cd}	67.66^{c}	$2.90^{(5)}$	49.32^{d}	61.60^{a}	$24.89^{(1)}$
Ezhome-4	76.00^{a}	77.33^{a}	$1.75^{(6)}$	59.15^{a}	62.86^{a}	$6.27^{(3)}$
Kanchana	68.76^{bc}	75.33^{a}	$9.55^{(2)}$	54.26^{bc}	60.80^{a}	$12.0^{(2)}$
Samyuktha	72.21^{ab}	74.66^{ab}	$3.39^{(4)}$	57.11^{ab}	60.04^{a}	$5.13^{(5)}$
CD (0.05)	**4.150***	**4.087***	-	**3.277***	**3.695***	-

*- 5% significant level

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative difference

R-Raw rice P-Parboiled rice

(75.33%), *Samyuktha* (74.66%) and *Aathira* (73.66%) but significantly different from control variety *Jyothi* (71.00%). However, variety *Aiswarya* (67.66%) was on par with control variety *Jyothi*. *Aathira* variety showed maximum relative difference in milling per cent after parboiling.

4.1.1.2. Head rice recovery

The head rice recovery in raw rice varied from 49.32 per cent (*Aiswarya*) to 59.15 per cent (*Ezhome-4*). Head rice recovery of *Aathira* was found to be on par with *Ezhome-4* and *Samyuktha* but significantly different from all other varieties.

The head rice recovery of parboiled rice varied from 53.66 (*Jyothi*) to 62.86 per cent (*Ezhome-4*). Variety *Ezhome-4* was on par with *Aiswarya* (61.60%), *Aathira* (61.40%), *Kanchana* (60.80%) and *Samyuktha* (60.04%) but significantly different from control variety *Jyothi* (53.66%). Variety *Aiswarya* showed maximum relative difference (24.89%) in head rice recovery after parboiling.

4.1.1.3. Thousand grain weight

Among raw red rice varieties, the highest thousand grain weight was observed in *Kanchana* (26.64g) rice variety (table 1b). It was followed by *Samyuktha* (25.44g), *Ezhome-4* (25.41g), *Aathira* (23.64g) and *Aiswarya* (22.96g). Control variety *Jyothi* recorded a thousand grain weight of 26.12g. According to DMRT there is no significant difference between samples.

In parboiled samples, the highest head rice recovery was recorded in control variety *Jyothi* (31.01g) followed by *Kanchana* (29.65g), *Samyuktha* (28.92g), *Aathira* (28.40g), *Aiswarya* (26.97g) and *Ezhome-4* (25.33g). On the basis of DMRT, the thousand grain weight of parboiled *Samyuktha* was found to be on par with that of *Aathira* and *Kanchana*. Variety *Aathira* showed maximum relative difference (20.13%) in thousand grain weight after parboiling.

Table 1b. Physical qualities of raw and parboiled rice

Varieties	Thousand grain weight (g)		Relative difference (%)	Volume weight (mm^3)		Relative difference (%)
	R	P		R		
Jyothi	26.12	31.01^{a}	$18.72^{(2)}$	12.16^{cd}	12.53^{bc}	$3.04^{(3)}$
Aathira	23.64	28.40^{ab}	$20.13^{(1)}$	13.87^{a}	14.17^{a}	$2.16^{(4)}$
Aiswarya	22.96	26.97^{bc}	$17.46^{(3)}$	11.84^{d}	12.27^{c}	$3.63^{(2)}$
Ezhome-4	25.41	25.67^{c}	$1.02^{(6)}$	12.83^{bc}	13.79^{ab}	$7.48^{(1)}$
Kanchana	26.64	29.65^{ab}	$11.29^{(5)}$	13.36^{ab}	13.58^{c}	$1.64^{(5)}$
Samyuktha	25.44	28.92^{ab}	$13.67^{(4)}$	12.40^{cd}	12.45^{c}	$0.40^{(6)}$
CD (0.05)	**NS**	**3.060***	-	**0.827***	**1.079***	-

*- 5% significant level

NS- Non significant

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

4.1.1.4. Volume weight

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Volume weight of raw rice varied from 11.84mm3 (*Aiswarya*) to 13.87mm3 (*Aathira*). Volume weight of *Aathira* was on par with *Kanchana* (13.36mm3) but significantly different from other varieties. However, variety *Samyuktha* (12.40mm3) was on par with control variety *Jyothi* (12.16mm3)

Volume weight of parboiled rice varied from 12.27mm3 (*Aiswarya*) to 14.17mm3 (*Aathira*). Variety *Kanchana* (13.58mm3) was on par with *Ezhome-4* (13.79mm3) and *Aathira* (14.17mm3) but significantly different from other varieties. *Ezhome-4* showed maximum relative difference (7.48%) in volume weight after parboiling.

4.1.1.5 Grain shape and size

The grain shape was determined by measuring grain length and width of rice. The grain length, grain width and L/B ratio of rice varieties are given in Table 2. Among red rice varieties, the highest grain length was recorded in control variety *Jyothi* (9.45mm) and the lowest was in *Ezhome-4* (5.63mm). The grain length of *Kanchana*, *Aathira*, *Aiswarya* and *Samyuktha* were found to be 6.76mm, 6.60mm, 6.40mm and 6.20mm respectively. On the basis of statistical analysis grain length of none of the varieties were on par with that of *Jyothi*. In parboiled samples also the highest grain length was observed in control variety *Jyothi* (9.45mm) which was followed by *Kanchana* (6.60mm), *Aiswarya* (6.33mm), *Samyuktha* (6.20mm), *Aathira* (5.73mm) and *Ezhome-4* (5.60mm).

The highest grain width in raw rice was observed in control variety *Jyothi* (2.89mm) it was followed by *Kanchana* (2.84mm), *Aathira* (2.68mm), *Samyuktha* (2.64mm), *Aiswarya* (2.48mm) and *Ezhome-4* (2.08mm). The grain width of all the rice varieties increased on parboiling. The highest grain width in parboiled samples was observed in *Jyothi* variety (3.16mm). The grain width of parboiled rice varieties *Kanchana*, *Aathira*, *Samyuktha*, *Aiswarya*, and *Ezhome-4* were found to be 2.99mm, 2.91mm, 2.68mm, 2.63mm, and 2.29mm respectively.

Table 2. Grain quality attributes of raw and parboiled rice varieties

Varieties	Grain length (mm)		Relative difference (%)	Grain width (mm)		Relative difference (%)	L/B ratio		Relative difference (%)
	R	P		R	P		R	P	
Jyothi	9.45^{a}	9.22^{a}	$-2.43^{(4)}$	2.89^{a}	3.16^{a}	$9.34^{(2)}$	3.24^{a}	2.98^{a}	$-8.02^{(4)}$
Aathira	6.60^{b}	5.73^{c}	$-13.18^{(6)}$	2.68^{bc}	2.91^{c}	$8.58^{(3)}$	2.42^{d}	2.00^{d}	$-17.35^{(6)}$
Aiswarya	6.40^{bc}	6.33^{b}	$-1.09^{(2)}$	2.48^{d}	2.63^{d}	$6.04^{(4)}$	2.55^{c}	2.40^{b}	$-5.88^{(2)}$
Ezhome-4	5.63^{d}	5.60^{c}	$-0.53^{(1)}$	2.08^{e}	2.29^{e}	$10.09^{(1)}$	2.71^{b}	2.43^{b}	$-10.33^{(5)}$
Kanchana	6.76^{b}	6.60^{b}	$-2.36^{(3)}$	2.84^{ab}	2.99^{b}	$5.28^{(5)}$	2.37^{d}	2.20^{c}	$-7.71^{(3)}$
Samyuktha	6.20^{cd}	5.80^{c}	$-6.45^{(5)}$	2.64^{cd}	2.68^{d}	$1.51^{(6)}$	2.34^{d}	2.17^{c}	$-7.26^{(1)}$
CD (0.05)	**0.618***	**0.418 ***	-	**0.615***	**0.070***	-	**0.085***	**0.099***	-

*- 5% significant level

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

The highest L/B ratio of 3.24 and 2.92 was observed in control variety *Jyothi* in both raw and parboiled samples. Among other red rice varieties, the highest L/B ratio of 2.71 was observed in *Ezhome-4* variety in raw samples which was followed by *Aiswarya* (2.55), *Aathira* (2.42), *Kanchana* (2.37) and *Samyuktha* (2.34). The second highest L/B ratio in parboiled rice was observed in *Ezhome-4* (2.43) which was followed by *Aiswarya* (2.40), *Kanchana* (2.20), *Samyuktha* (2.17) and *Aathira* (2.00). Variety *Samyuktha* showed maximum relative difference in L/B ratio of rice grain.

4.1.2. Physical qualities of rice flour

Rice flour prepared from raw and parboiled rice varieties were evaluated for various physical characteristics like bulk density, water absorption index, water solubility index and retrogradation property. The results are presented in Table 3 and Table 4.

4.1.2.1. Bulk density

Bulk density of rice flour prepared from raw and parboiled rice varieties is given in Table 3. Bulk density of raw rice ranged from 0.65g/ml (*Jyothi*) to 0.72g/ml (Aatthira and *Ezhome-4*). *Kanchana*, *Aiswarya* and *Samyuktha* obtained a bulk density of 0.71g/ml, 0.68g/ml and 0.66 g/ml respectively.

In case of parboiled rice flour, bulk density was in the range of 0.57g/ml (*Samyuktha* and *Jyothi*) to 0.66g/ml (*Kanchana*). Bulk density decreased considerably after parboiling. Bulk density of 0.65g/ml, 0.61g/ml and 0.59g/ml was observed in *Aathira*, *Aiswarya* and *Ezhome-4* respectively. Variety *Kanchana* was on par with variety *Aathira* and *Aiswarya* but significantly different from other varieties. However, variety *Samyuktha* was on par with control variety *Jyothi*. *Kanchana* variety showed maximum increase in bulk density after parboiling.

Table 3. Physical qualities of raw and parboiled rice flour

Varieties	Bulk density (g/ml)		Relative difference (%)	Water absorption index (WAI)		Relative difference (%)	Water solubility index (WSI)		Relative difference (%)
	R	P		R	P		R	P	
Jyothi	0.65^{c}	0.57^{b}	$-12.30^{(4)}$	25.56^{a}	23.60	$-7.66^{(5)}$	0.47^{bc}	0.54^{c}	$14.89^{(5)}$
Aathira	0.72^{a}	0.65^{a}	$-9.72^{(2)}$	25.31^{a}	23.71	$-6.32^{(3)}$	0.45^{c}	0.55^{bc}	$22.22^{(1)}$
Aiswarya	0.68^{abc}	0.61^{ab}	$-10.29^{(3)}$	25.61^{a}	22.26	$-11.32^{(6)}$	0.49^{bc}	0.57^{abc}	$16.32^{(3)}$
Ezhome-4	0.72^{a}	0.59^{b}	$-18.05^{(6)}$	23.71^{ab}	22.04	$-7.04^{(4)}$	0.57^{a}	0.61^{a}	$7.01^{(6)}$
Kanchana	0.71^{ab}	0.66^{a}	$-7.04^{(1)}$	22.91^{b}	22.67	$-1.04^{(1)}$	0.46^{bc}	0.56^{bc}	$21.73^{(2)}$
Samyuktha	0.66^{bc}	0.57^{b}	$-13.63^{(5)}$	22.46^{b}	22.17	$-1.29^{(2)}$	0.51^{b}	0.59^{ab}	$15.68^{(4)}$
CD (0.05)	**0.050***	**0.053***	-	**2.096***	**NS**	-	**0.046***	**0.056***	-

*- 5% significant level

NS- Non significant

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

4.1.2.2. Water absorption index

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Water absorption index of raw rice flour varied from 22.46 (*Samyuktha*) to 25.61 (*Aiswarya*). Variety *Aiswarya* was on par with control variety *Jyothi* (25.56) and *Aathira* (25.31).

A decrease in water absorption index was observed in all rice varieties after parboiling.In case of parboiled rice flour, the highest water absorption index was observed in *Aathira* (23.71) rice variety followed by *Jyothi* (23.60), *Kanchana* (22.67), *Aiswarya* (22.26), *Samyuktha* (22.17) and *Ezhome-4* (22.04). However, there was no significant difference among the varieties. Variety *Kanchana* showed maximum relative difference (21.73%) in water absorption index after parboiling.

4.1.2.3. Water solubility index

Among rice flour prepared from raw rice varieties water solubility index was in the range of 0.45 (*Aathira*) to 0.57 (*Ezhome-4*. Water absorption index of 0.51, 0.49, 0.47 and 0.46 was observed in *Samyuktha*, *Aiswarya*, *Jyothi* and *Kanchana*.

An increase in water solubility index was observed in all rice varieties after parboiling. Highest water solubility index of parboiled rice was noticed in *Ezhome-4* (0.61) rice variety. Control variety *Jyothi* obtained a water solubility index of 0.54 which was lower than all the other red rice varieties. *Samyuktha*, *Aiswarya*, *Kanchana* and *Aathira* obtained a water solubility index of 0.59, 0.57, 0.56 and 0.55 respectively. *Aathira* showed maximum relative difference in water solubility index after parboiling.

4.1.2.4. Retrogradation property

Retrogradation property of rice flour prepared from raw and parboiled rice varieties were studied by evaluating the syneresis per cent and is presented in Table 4.

Table 4. Retrogradation property of raw and parboiled rice flour

Varieties	Days								Relative difference (%)
	3rd day		6th day		9th day		12th day		
	R	P	R	P	R	P	R	P	
Jyothi	10.73^{d}	10.66^{d}	14.20^{d}	14.43^{d}	18.26^{e}	18.60^{e}	25.60^{d}	29.66^{d}	$15.85^{(2)}$
Aathira	12.43^{bc}	13.26^{bc}	17.06^{c}	18.13^{b}	21.23^{d}	22.13^{d}	28.03^{c}	26.16^{e}	$-6.67^{(6)}$
Aiswarya	11.70^{c}	12.63^{c}	14.93^{d}	12.26^{c}	19.03^{e}	22.30^{d}	26.30^{d}	30.76^{c}	$16.95^{(1)}$
Ezhome-4	12.86^{b}	13.10^{c}	17.10^{c}	17.73^{b}	23.53^{c}	25.03^{c}	32.16^{b}	32.23^{b}	$0.21^{(5)}$
Kanchana	13.10^{b}	13.83^{b}	18.33^{b}	19.50^{a}	25.26^{b}	26.26^{b}	31.60^{b}	32.16^{b}	$1.77^{(4)}$
Samyuktha	14.20^{a}	14.70^{a}	19.60^{a}	20.03^{a}	26.73^{a}	27.40^{a}	33.66^{a}	35.06^{a}	$4.15^{(3)}$
CD (0.05)	**0.856***	**0.810***	**0.828***	**0.886***	**1.137***	**0.853***	**1.268***	**0.939***	-

*- 5% significant level

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

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Among rice flour prepared with raw rice varieties *Samyuktha* obtained the highest syneresis during 3rd day of observation, which increased gradually on 6th, 9th, and 12th day. The lowest syneresis during 3rd day was observed in control variety *Jyothi*. All raw red rice varieties showed a gradual increase in syneresis percentage from 3rd day to 12th day of study. At the end of 12th day of study, the highest syneresis was noticed in *Samyuktha* rice variety and the lowest was observed in control variety *Jyothi*.

In case of parboiled rice flour the highest syneresis during 3rd day was observed in *Samyuktha* rice variety and the lowest was in control variety *Jyothi*. All parboiled rice varieties showed a gradual increase in syneresis percentage from 3rd day to 12th day. At the end of the study, the highest syneresis percentage was observed in *Samyuktha* rice variety and lowest was observed in *Aathira* rice variety.

4.1.3. Cooking qualities of raw and parboiled rice

Cooking qualities like gelatinization temperature index, cooking time, water uptake, volume expansion, amylose content, gel consistency and grain elongation were analysed in raw and parboiled rice varieties and compared with control variety *Jyothi*. The results are as follows.

4.1.3.1. Gelatinization temperature index

All varieties of rice subjected to alkali digestion test were visually observed to evaluate the degree of disintegration in alkali. It was found that the variety *Samyuktha* showed a low gelatinization temperature as the grain was dispersed and merged with collar in raw samples. Varieties *Ezhome-4*, *Aathira*, *Jyothi Aiswarya* and *Kanchana* showed intermediate gelatinization temperature as the grains were swollen and collar complete and wide when treated with alkali. In parboiled samples, *Jyothi*, *Aathira*, *Ezhome-4* and *Kanchana* has shown high gelatinization temperature index. *Aiswarya* and *Samyuktha* had shown intermediate gelatinization temperature after parboiling. Gelatinization temperature index of different rice varieties are presented in Plate.

Jyothi

Aathira

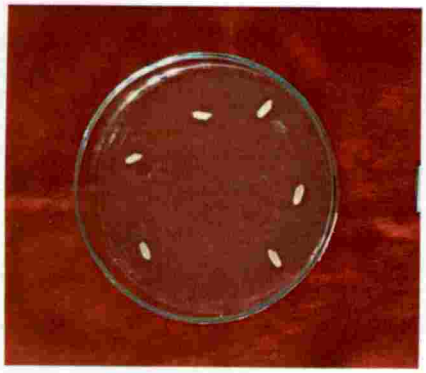
Aiswarya

Ezhome-4

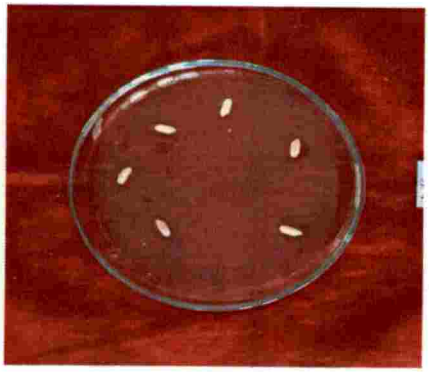
Kanchana

Samyuktha

Plate 2. Gelatinisation temperature index of raw rice varieties

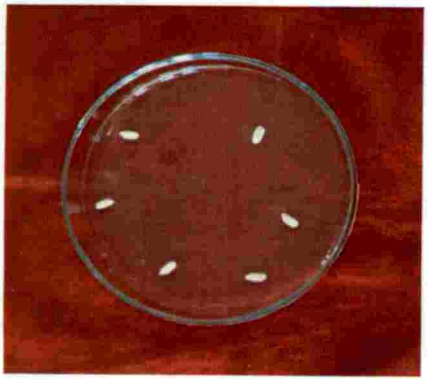


Jyothi



Aathira

Aiswarya



Ezhome-4

Kanchana

Samyuktha

Plate 3. Gelatinisation temperature index of parboiled rice varieties

4.1.3.2. Cooking time

The cooking time was recorded in raw and parboiled rice varieties and the values are given in Table 5a. The cooking time taken by the rice varieties varied from 21.66 minutes (*Aiswarya*) to 27 minutes (*Ezhome-4*) in raw samples. In parboiled varieties, cooking time varied from 31.66 minutes (*Kanchana*) to 37.66 minutes (*Aiswarya*).

In raw rice varieties maximum cooking time was recorded in *Ezhome-4* (27minutes) variety and minimum was recorded in *Samyuktha* (20.33minutes) variety. *Kanchana*, *Jyothi*, *Aathira* and *Aiswarya* had a cooking time of 25.66minutes, 23minutes, 22.66minutes and 20.33 minutes respectively. On the basis of statistical analysis, cooking time of control variety *Jyothi* was found to be on par with that of *Aathira* rice variety. Cooking time of all rice varieties were increased on parboiling. Maximum cooking time in parboiled samples was recorded in *Aiswarya* (38minutes) variety and the minimum was recorded in *Samyuktha* (28minutes) variety. Control variety *Jyothi* obtained a value of 32 minutes. *Ezhome-4*, *Aathira* and *Kanchana* recorded a cooking time of 37, 35 and 30 minutes. According to DMRT cooking time of *Ezhome-4* was found to be on par with that of *Aathira* rice variety. *Aiswarya* rice variety showed maximum relative difference (73.86%) in cooking time after parboiling.

4.1.3.3. Water uptake

Among raw red rice varieties water uptake was in the range of 8.71ml (*Ezhome-4*) to 7.39 ml (*Samyuktha*). Variety *Ezhome-4* was on par with control variety *Jyothi* (8.70ml) and *Aathira* (8.56ml). Variety *Kanchana* (7.58ml) was on par with variety *Samyuktha* (7.39ml).

Water uptake was higher in parboiled samples in all the varieties. The highest water uptake was recorded in *Ezhome-4* (12.80ml) variety and lowest was recorded in *Samyuktha* (8.83ml) variety. *Aiswarya*, *Jyothi*, *Aathira* and *Kanchana* obtained a water uptake of 11.46, 9.50, 9.40, and 9.33ml respectively. On the basis of statistical analysis, control variety *Jyothi* was on par with *Aathira*,

Table 5a. Cooking qualities of raw and parboiled rice

Varieties	Cooking time (min)		Relative difference (%)	Water uptake (g/ml)		Relative difference (%)	Volume expansion		Relative difference (%)
	R	P		R	P		R	P	
Jyothi	23^{bc}	34^{bc}	$47.82^{(3)}$	8.70^{a}	9.50^{c}	$9.15^{(6)}$	5.38^{a}	5.70^{a}	$5.94^{(3)}$
Aathira	22.66^{bc}	35.33^{ab}	$55.91^{(2)}$	8.56^{a}	9.40^{c}	$9.81^{(5)}$	4.95^{b}	4.97^{bc}	$0.40^{(4)}$
Aiswarya	21.66^{c}	37.66^{a}	$73.86^{(1)}$	8.16^{b}	11.46^{b}	$40.44^{(2)}$	4.38^{c}	4.87^{bc}	$11.18^{(1)}$
Ezhome-4	27^{a}	37.33^{ab}	$38.25^{(5)}$	8.71^{a}	12.80^{a}	$46.95^{(1)}$	5.43^{a}	5.20^{b}	$-4.23^{(5)}$
Kanchana	25.66^{ab}	31.66^{cd}	$23.38^{(6)}$	7.58^{c}	9.33^{c}	$23.08^{(3)}$	4.83^{b}	5.13^{b}	$6.21^{(2)}$
Samyuktha	20.33^{c}	28.33^{d}	$39.35^{(4)}$	7.39^{c}	8.83^{c}	$19.48^{(4)}$	5.43^{c}	4.77^{c}	$-12.15^{(6)}$
CD (0.05)	**3.355***	**3.533***	-	**0.281***	**0.927***	-	**0.414***	**0.338***	-

*- 5% significant level

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

Kanchana and *Samyuktha*. *Ezhome-4* variety showed maximum relative difference in water uptake after parboiling.

4.1.3.4. Volume expansion ratio

Volume expansion ratio of the different samples were given in the above Table 5a. In raw samples the highest volume expansion ratio was recorded in *Ezhome-4* (5.43) variety and the lowest was recorded in *Samyuktha* (4.35). The second highest value was recorded in control variety *Jyothi* (5.38) followed by *Aathira* (4.95), *Kanchana* (4.83) and *Aiswarya* (4.38). According to DMRT volume expansion of *Ezhome-4* was found to be on par with that of control variety *Jyothi*.

In parboiled samples the highest volume expansion ratio was recorded in *Jyothi* (5.70) followed by *Ezhome-4* (5.20), *Kanchana* (5.13), *Aathira* (4.97) and *Aiswarya* (4.87). The lowest volume expansion of 4.77 was recorded in *Samyuktha* variety. On the basis of statistical analysis volume expansion of *Ezhome-4* was found to be on par with that of *Kanchana*. *Aiswarya* variety showed maximum relative difference in volume expansion after parboiling.

4.1.3.5. Amylose content

In raw samples the highest amylose content was recorded in *Aathira* (24.90%) rice variety followed by *Ezhome-4* (24.58%), *Aiswarya* (24.52%), *Jyothi* (24.20%), *Kanchana* (23.98%) and *Samyuktha* (23.23%). In the case of parboiled samples, the highest amylose content was recorded in *Ezhome-4* (24.54%) followed by *Aathira* (24.50%), *Aiswarya* (24.23%), *Jyothi* (24.16%) *Kanchana* (23.44%) and *Samyuktha* (23.03%).On the basis of statistical analysis variation in amylose content in both raw and parboiled samples were non -significant. A decrease in amylose content was observed in all parboiled rice varieties when compared with raw. Variety *Ezhome-4* showed maximum relative difference in amylose content after parboiling (Table 5b).

Table 5b. Cooking qualities of raw and parboiled rice

Varieties	Amylose content (%)		Relative difference (%)	Gel consistency (mm)		Relative difference (%)	Grain elongation ratio		Relative difference (%)
	R	P		R	P		R	P	
Jyothi	24.20	24.16	-0.16 (1)	57.30^{d}	24.66^{d}	-56.96 (6)	1.70	1.44^{b}	-15.29 (6)
Aathira	24.90	24.50	-1.60 (4)	58.80^{c}	39.33^{bc}	-33.11 (3)	1.75	1.57^{a}	-10.28 (4)
Aiswarya	24.52	24.23	-1.18 (3)	60.44^{b}	51.33^{a}	-15.07 (1)	1.79	1.52^{ab}	-15.08 (5)
Ezhome-4	24.58	24.54	-0.16 (1)	55.76^{e}	42^{b}	-24.67 (2)	1.52	1.55^{a}	1.97 (1)
Kanchana	23.98	23.44	-2.25 (5)	61.47^{ab}	35^{c}	43.06 (5)	1.77	1.61^{a}	-9.03 (3)
Samyuktha	23.23	23.03	-0.86 (2)	62.21^{a}	36^{c}	-42.13 (4)	1.47	1.43^{b}	-2.72 (2)
CD (0.05)	**NS**	**NS**	-	**1.498***	**5.187***	-	**NS**	**0.106***	-

*- 5% significant level

NS- Non significant

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

65

4.1.3.6. Gel consistency

Gel consistency of rice was determined by measuring gel length and is presented in table 5b. The gel length of raw rice varieties varied from55.76mm (*Ezhome-4*) to 62.21mm (*Samyuktha*). *Kanchana*, *Aiswarya*, *Aathira*, *Jyothi* and *Ezhome-4* observed a gel length of 61.47mm, 60.44mm, 58.80mm, 57.30mm and 55.76mm. Variety *Samyuktha* was on par with variety *Kanchana* but significantly different from other varieties.

In parboiled rice varieties, gel length varied from 24.66mm (*Jyothi*) to 51.33mm (*Aiswarya*). Gel length of 42mm, 39.33mm, 36mm and 35mm was observed in *Ezhome-4*, *Aathira*, *Samyuktha* and *Kanchana* respectively. A decrease in gel length was observed in all the rice varieties on parboiling. Variety *Samyuktha* was on par with variety *Kanchana*.

4.1.3.7. Grain elongation ratio

In raw samples grain elongation ratio was varied from1.47 (*Samyuktha*) to 1.79 (*Aiswarya*). Other red rice varieties *Jyothi*, *Aathira*, *Kanchana* and *Ezhome-4* recorded a grain elongation ratio of 1.7, 1.75, 1.77 and 1.52 respectively. On the basis of DMRT there is no significant variation in raw samples. . A decrease in grain elongation ratio was observed in all the rice varieties on parboiling. In parboiled samples the highest grain elongation ratio was recorded in *Kanchana* (1.61) followed by *Aathira* (1.57), *Ezhome-4* (1.55), *Aiswarya* (1.52), *Jyothi* (1.44) and *Samyuktha* (1.43). According to statistical analysis *Aathira* was found to be on par with that of *Ezhome-4*. Control variety *Jyothi* was found to be on par with that of *Samyuktha* (Table 5b).

4.1.4. Nutritional qualities of rice

The nutritional qualities of rice varieties like moisture, starch, protein, fat, crude fibre, thiamine, calcium, zinc, iron, phosphorus, *in vitro* digestibility of starch and oil content in rice bran were evaluated. The results on the chemical and nutritional qualities of different rice varieties are presented in Table 6a, 6b, 6c and 6d.

4.1.4.1. Moisture

The highest moisture content in raw rice was observed in *Aiswarya* (12.5 %) rice variety was followed by *Samyuktha* (11.51%), *Ezhome-4* (11.3%), *Aathira* (10.8%), *Kanchana* (10.7%) and the lowest was in control variety *Jyothi* (10.5%).

The highest moisture content in parboiled samples was observed in *Aiswarya* (11.56%) rice variety and the lowest was in control variety *Jyothi* (9.70%). *Samyuktha*, *Aathira*, *Kanchana* and *Ezhome-4* obtained a moisture content of 10.90 per cent, 10.70 per cent, 10.50 per cent and 9.73 per cent respectively. *Ezhome-4* was on par with that of control variety *Jyothi* with respect to moisture content. A decrease in moisture content was observed in all the parboiled rice varieties.

4.1.4.2. Starch

Starch content of raw rice varieties were in the range of 70.50g/100g (*Aiswarya*) to 67.26g/100g (*Kanchana*). Variety *Samyuktha* (68.33g/100g) was on par with *Aathira* (68.23g/100g) but distinctly differ from other varieties. Variety *Aiswarya* is significantly superior to all the varieties.

Starch content of parboiled rice varieties were in the range of 67.43g/100g (*Ezhome-4*) to 62.40g/100g (*Kanchana*). Starch content of 65.66g/100g, 64.23g/100g and 63.10g/100g was observed in *Aathira*, *Aiswarya*, *Jyothi* and *Samyuktha* respectively. Variety *Aathira* was on par with variety *Aiswarya*. A decrease in starch content was observed in all parboiled varieties after parboiling. The relative difference observed was minimum in parboiled *Jyothi*.

4.1.4.3. Protein

The protein content of rice varieties was assessed and found that among raw red rice varieties, highest protein was observed in *Ezhome-4* (5.50g/100g) and the lowest was in *Samyuktha* (4.70g/100g). *Jyothi*, *Kanchana*, *Aathira* and *Aiswarya* obtained a protein content of 5.47g/100g, 5.34g/100g, 5.00g/100g and 4.94g/100g

Table 6a. Nutritional qualities of raw and parboiled rice

Varieties	Moisture (%)		Relative difference (%)	Starch (g)		Relative difference (%)	Protein (g)		Relative difference (%)
	R	P		R	P		R	P	
Jyothi	10.5^{c}	9.70^{d}	$-7.61^{(5)}$	65.83^{d}	64.23^{c}	$-2.43^{(1)}$	5.47^{ab}	3.12	$-42.96^{(6)}$
Aathira	10.8^{abc}	10.70^{b}	$-0.92^{(1)}$	68.23^{bc}	65.66^{b}	$-3.76^{(3)}$	5.00^{bc}	3.63	$-27.4^{(2)}$
Aiswarya	12.5^{a}	11.56^{a}	$-7.52^{(4)}$	70.50^{a}	65.66^{b}	$-6.86^{(4)}$	4.94^{cd}	3.36	$-31.98^{(3)}$
Ezhome-4	11.3^{bc}	9.73^{cd}	$-13.89^{(6)}$	69.36^{ab}	67.43^{a}	$-2.78^{(2)}$	5.50^{a}	3.53	$-35.81^{(6)}$
Kanchana	10.7^{ab}	10.50^{bc}	$-1.86^{(2)}$	67.26^{cd}	62.40^{d}	$-7.22^{(5)}$	5.34^{abc}	3.32	$-37.82^{(5)}$
Samyuktha	11.51^{a}	10.90^{ab}	$-5.29^{(3)}$	68.33^{bc}	63.10^{cd}	$-7.65^{(6)}$	4.70^{d}	3.75	$-20.21^{(1)}$
CD (0.05)	**1.128***	**0.774***	-	**1.619***	**1.257***	-	**0.491***	**NS**	-

*- 5% significant level

NS- Non significant

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

respectively. The protein content of *Ezhome-4* was on par with *Kanchana* and control variety *Jyothi*.

A considerable decrease in protein content was observed in parboiled samples. The highest protein content in parboiled samples was noticed in *Samyuktha* (3.75g/100g) rice variety which was followed by *Aathira* (3.63g/100g), *Ezhome-4* (3.53g/100g), *Aiswarya* (3.36g/100g) and *Kanchana* (3.32g/100g). Control variety *Jyothi* obtained a lowest protein content of 3.16 g/100g. No significant difference in protein content was observed between parboiled samples. *Samyuktha* variety showed maximum relative difference in protein content after parboiling. The relative difference observed in protein content on parboiling was the lowest in *Samyuktha* variety.

4.1.4.4. Fat

Fat content of raw rice varieties varied from 0.24g/100g (*Samyuktha*) to 0.35g/100g (*Aathira*). Fat content of *Aathira* (0.35g/100g) was found to be on par with *Kanchana* (0.30g/100g) and *Jyothi* (0.32g/100g) and significantly superior to all other rice varieties.

A decrease was observed in fat content after parboiling. Fat content of parboiled rice varieties was in the range of 0.31g/100 of (*Samyuktha*) to 0.48g/100g (*Aathira*). Variety *Aathira* was on par with variety *Kanchana* (0.43g/100g) but significantly different from other varieties. *Samyuktha* variety is significantly inferior to all other varieties. Variety *Ezhome-4* showed maximum relative difference in fat content after parboiling (Table 6b).

4.1.4.5. Crude fibre

The fibre content of raw rice varieties were determined and found that the highest fibre content of 0.31g/100g was noticed in both *Ezhome-4* and *Samyuktha* which was on par with variety *Kanchana*. The lowest fibre content was observed in control variety *Jyothi* (0.18g/100g). *Kanchana*, *Aiswarya* and *Aathira* obtained a fibre content of 0.28g/100g, 0.25g/100g and 0.21g/100g respectively. The fibre

Table 6b. Nutritional qualities of raw and parboiled rice

Varieties	Fat (g)		Relative difference (%)	Fibre (g)		Relative difference (%)	Thiamine (mg)		Relative difference (%)
	R	P		R	P		R	P	
Jyothi	0.32^{ab}	0.38^{b}	$-15.79^{(1)}$	0.18^{c}	0.19^{b}	$5.55^{(3)}$	0.060	0.087	$45^{(1)}$
Aathira	0.35^{a}	0.48^{a}	$-27.08^{(3)}$	0.21^{c}	0.22^{b}	$4.76^{(4)}$	0.063	0.073	$15.87^{(2)}$
Aiswarya	0.27^{bcd}	0.40^{b}	$-32.5^{(5)}$	0.25^{b}	0.27^{a}	$8^{(1)}$	0.080	0.086	$7.5^{(5)}$
Ezhome-4	0.25^{cd}	0.38^{b}	$-34.21^{(6)}$	0.31^{a}	0.31^{a}	-	0.063	0.071	$12.69^{(4)}$
Kanchana	0.30^{abc}	0.43^{ab}	$-30.23^{(4)}$	0.28^{a}	0.30^{a}	$7.14^{(2)}$	0.070	0.080	$14.28^{(3)}$
Samyuktha	0.24^{d}	0.31^{c}	$-22.58^{(2)}$	0.31^{ab}	0.32^{a}	$3.22^{(5)}$	0.060	0.070	$1.66^{(6)}$
CD (0.05)	**0.050***	**0.050***	-	**0.040***	**0.048***	-	**NS**	**NS**	-

*- 5% significant level

NS- Non significant

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

content of control variety *Jyothi* was found to be on par with that of *Aathira* rice variety.

The highest fibre content in parboiled samples was noticed in *Ezhome-4* (0.31g) which was on par with *Samyuktha* (0.32g/100g), *Aiswarya* (0.27g/100g), *Kanchana* (0.30g/100g). The fibre content of control variety *Jyothi* was found to be on par with that of

Aathira. Variety *Aiswarya* showed maximum relative difference in fibre content after parboiling (Table 6b).

4.1.4.6. Thiamine

The thiamine content of raw rice varieties were estimated and found that the highest thiamine content was reported in *Aiswarya* (0.08mg/100g) and the lowest of 0.06mg/100g was recorded in control variety *Jyothi* and *Samyuktha*. *Kanchana*, *Ezhome-4* and *Aathira* obtained a thiamine content of 0.07mg/100g, 0.063mg/100g and 0.063mg/100g respectively.

A slight increased thiamine content was observed in parboiled red rice varieties. In parboiled samples the highest thiamine content was observed in control variety *Jyothi* (0.087mg/100g) followed by *Aiswarya* (0.086mg/100g), *Kanchana* (0.08mg/100g), *Aathira* (0.073mg/100g), *Samyuktha* (0.07mg/100g) and *Ezhome-4* (0.06mg/100g). The variation in both raw and parboiled samples were non-significant with respect to thiamine content. Control variety *Jyothi* showed maximum relative difference in thiamine content after parboiling (Table 6b).

4.1.4.7 Calcium

The calcium content of raw rice varieties was determined and found that the highest calcium content was observed in *Kanchana* (5.76mg/100g) and the lowest was in *Aiswarya* (4.90mg/100g). *Aathira*, *Jyothi*, Samuktha and *Ezhome-4* obtained a calcium content of 5.63mg/100g, 5.46mg/100g, 5.43mg/100g and

Table 6c. Nutritional qualities of raw and parboiled rice

Varieties	Calcium (mg)		Relative difference (%)	Zinc (mg)		Relative difference (%)	Iron (mg)		Relative difference (%)
	R	P		R	P		R	P	
Jyothi	5.46^{a}	5.70	$4.39^{(5)}$	1.09^{c}	1.25^{c}	$14.67^{(1)}$	0.61^{a}	0.65^{a}	$6.55^{(4)}$
Aathira	5.63^{a}	6.03	$7.10^{(3)}$	1.32^{a}	1.34^{ab}	$1.51^{(5)}$	0.45^{c}	0.50^{c}	$11.11^{(1)}$
Aiswarya	4.90^{b}	5.93	$21.02^{(1)}$	1.26^{b}	1.30^{b}	$3.17^{(3)}$	0.52^{b}	0.54^{b}	$3.84^{(6)}$
Ezhome-4	5.40^{a}	5.50	$1.85^{(6)}$	1.27^{ab}	1.31^{ab}	$3.14^{(4)}$	0.50^{b}	0.55^{b}	$10^{(3)}$
Kanchana	5.76^{a}	6.06	$5.20^{(4)}$	1.32^{a}	1.34^{ab}	$1.51^{(6)}$	0.39^{d}	0.43^{d}	$10.25^{(2)}$
Samyuktha	5.43^{a}	5.90	$8.65^{(2)}$	1.25^{b}	1.35^{a}	$8^{(2)}$	0.44^{c}	0.46^{d}	$4.54^{(5)}$
CD (0.05)	**0.432***	**NS**	-	**0.055***	**0.046***	-	**0.046***	**0.040***	-

*- 5% significant level

NS- Non significant

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

5.40mg/100g respectively. All the varieties except *Aiswarya* was on par with control variety *Jyothi*.

The highest calcium content in parboiled samples was reported in *Kanchana* (6.06mg) which was followed by *Aathira* (6.03mg/100g), *Aiswarya* (5.93mg/100g), *Samyuktha* (5.90mg/100g), *Jyothi* (5.70mg/100g) and *Ezhome-4* (5.50mg/100g). There was no significant difference in calcium between samples of parboiled rice varieties. Variety *Aiswarya* showed maximum relative difference in calcium content after parboiling.

4.1.4.8. Zinc

The zinc content of rice varieties was assessed and which was in the range of 1.32mg/100g (*Aathira*, *Kanchana*) to 1.26mg/100g (*Aiswarya*). Variety *Aathira* was on par with variety *Kanchana* and Ezome-4 but significantly different from other varieties. Control variety *Jyothi* (1.09mg/100g) is significantly inferior to all other varieties.

In parboiled rice varieties, zinc content varied from 1.35mg/100g (*Samyuktha*) to 1.25mg/100g (*Jyothi*). Variety *Samyuktha* (1.35mg/100g), *Aathira* (1.34mg/100g) *Kanchana* (1.34mg/100g) and *Ezhome-4* (1.31mg/100g) were on par each other. Control variety *Jyothi* showed maximum relative difference in zinc content after parboiling.

4.1.4.9. Iron

The highest iron content in raw rice varieties was noticed in control variety *Jyothi* (0.61mg/100g) and lowest was observed in *Kanchana* (0.39mg/100g). Jyohi was significantly superior to all other varieties in iron content in both raw and parboiled rice. Iron content of 0.52mg/100g, 0.50mg/100g, 0.45mg/100g and 0.44mg/100g, was obtained in varieties *Aiswarya*, *Ezhome-4*, *Aathira* and *Samyuktha* respectively. Iron content of *Aiswarya* was found to be on par with that of *Ezhome-4*.

Control variety *Jyothi* obtained a highest iron content of 0.65mg in parboiled rice varieties and it was followed by *Ezhome-4* (0.55mg/100g,), *Aiswarya* (0.54mg/100g,), *Aathira* (0.50mg/100g,), *Samyuktha* (0.46mg/100g,) and *Kanchana* (0.43mg/100g,). The iron content of *Samyuktha* was found to be on par with that of *Kanchana*. The iron content of none of the varieties was on par with that of control variety *Jyothi*. Variety *Aathira* showed maximum relative difference in iron content after parboiling.

4.1.4.10. Phosphorus

The phosphorus content of raw red rice varieties was estimated and is furnished in Table 6d. The highest phosphorus content was observed in *Aiswarya* (131.96mg/100g) and the lowest in *Aathira* (127.60mg/100g). Varieties *Samyuktha*, *Ezhome-4*, *Jyothi* and *Kanchana* obtained a phosphorus content of 131.36mg/100g, 130.36mg/100g, 130.10mg/100g and 129.83mg/100g respectively. Phosphorus content of *Aiswarya* was found to be on par with that of *Samyuktha* and Ezhome -4. Control variety *Jyothi* recorded a phosphorus content on par with that of *Kanchana*.

In parboiled rice varieties the highest phosphorus content was noticed in *Aiswarya* (132.60mg/100g) and it was followed by *Kanchana* (132.46mg/100g), *Samyuktha* (132.43mg/100g), *Ezhome-4* (132.23mg/100g), *Jyothi* (131.40mg/100g) and *Aathira* (129.93mg/100g). There is no significant difference observed between rice varieties. *Kanchana* variety showed maximum relative difference in phosphorus content after parboiling.

4.1.4.11. *In vitro* digestibility of starch

In vitro digestibility of starch from different raw and parboiled rice varieties are given in Table 6d. The highest *in vitro* digestibility was observed in *Aathira* (79.06%) and it was significantly different from other varieties which was followed by *Jyothi* (77.26%), *Samyuktha* (75.33%), *Kanchana* (74.43%), *Aiswarya* (72.93%) and *Ezhome-4* (72.46%). The *in vitro* starch digestibility of none of the varieties was on par with that of control variety *Jyothi*.

Table 6d. Nutritional qualities of raw and parboiled rice

Varieties	Phosphorus (mg)		Relative difference (%)	*In vitro* digestibility of starch		Relative difference (%)	Oil content in rice bran (mg)		Relative difference (%)
	R	P		R	P		R	P	
Jyothi	130.10^{b}	131.40	$0.99^{(4)}$	77.26^{b}	76.16^{a}	$-1.42^{(1)}$	1.26^{c}	1.86	$47.61^{(1)}$
Aathira	127.60^{c}	129.93	$1.82^{(2)}$	79.06^{a}	76.90^{a}	$-2.73^{(3)}$	1.76^{ab}	2.16	$22.72^{(3)}$
Aiswarya	131.96^{a}	132.60	$0.48^{(6)}$	72.93^{de}	71.40^{b}	$-2.09^{(2)}$	1.46^{bc}	1.86	$27.3^{(9)}$
Ezhome-4	130.36^{ab}	132.23	$1.43^{(3)}$	72.46^{e}	70.06^{b}	$-3.31^{(4)}$	2.00^{a}	2.00	-
Kanchana	129.83^{b}	132.46	$2.02^{(1)}$	74.43^{cd}	71.13^{b}	$-4.43^{(6)}$	1.80^{ab}	1.90	$5.55^{(4)}$
Samyuktha	131.36^{ab}	132.43	$0.81^{(5)}$	75.33^{c}	72.16^{b}	$-4.20^{(5)}$	2.10^{a}	2.06	$-1.90^{(5)}$
CD (0.05)	**1.641***	**NS**	-	**1.763***	**2.391***	-	**0.363***	**NS**	-

*- 5% significant level

NS- Non significant

Values having different superscripts differ significantly in DMRT

Figures in parenthesis are rankings based on relative increase

R-Raw rice P-Parboiled rice

The highest starch digestibility in parboiled samples was noticed in *Aathira* (76.16) and the lowest was in *Ezhome-4* (70.06%). Varieties *Jyothi*, *Samyuktha*, *Aiswarya* and *Kanchana* obtained a starch digestibility of 76.16, 72.16, 71.40 and 71.13 per cent respectively. The *in vitro* starch digestibility of *Aathira* was found to on par with that of control variety *Jyothi*. A decrease in *in vitro* digestibility was observed in all the rice varieties after parboiling.

4.1.4.12. Oil content in rice bran

The bran oil content of rice varieties was assessed and is presented in Table 6d. It was found that among raw red rice varieties the highest oil content was noticed in *Samyuktha* (2.10g) and it was followed by *Ezhome-4* (2.00g), *Kanchana* (1.80g), *Aathira* (1.76g), *Aiswarya* (1.46g) and control variety *Jyothi* (1.26g).

In parboiled samples the highest oil content was observed in *Aathira* (2.16g) and the lowest was in *Aiswarya* (1.86g) and control variety *Jyothi* (1.86g). Varieties *Samyuktha*, *Ezhome-4* and *Kanchana* obtained oil content of 2.06g, 2.00g and 1.90g respectively. There is no significant difference between samples was observed for oil content in parboiled rice. Control variety *Jyothi* showed maximum relative difference in rice bran oil content after parboiling.

4.2.1. Organoleptic evaluation of table rice

The mean scores of different quality attributes of table rice prepared with both raw and parboiled rice are given in Table 7. The highest mean score for appearance was observed in *Aiswarya* (7.51) and lowest in *Ezhome-4* (6.26). The mean rank scores of *Aiswarya* and *Ezhome-4* are 4.59 and 1.44 respectively. *Jyothi*, *Aathira*, *Kanchana* and *Samyuktha* obtained mean scores of 7.44, 7.24, 7.13 and 6.86 with mean rank scores of 4.41, 4.00, 3.56 and 3.00 respectively.

The highest mean score for appearance in parboiled rice was recorded in control variety *Jyothi* (7.88) with a mean rank score of 4.59 and the lowest was recorded in *Ezhome-4* (6.64) with a mean rank score of 1.78. *Kanchana*, *Aiswarya*

Jyothi

Aathira

Aiswarya

Ezhome-4

Kanchana

Samyuktha

Plate 4. Table rice prepared with various raw rice varieties

Jyothi

Aathira

Aiswarya

Ezhome-4

Kanchana

Samyuktha

Plate 5. Table rice prepared with various parboiled rice varieties

and *Samyuktha* obtained mean score of 7.55, 7.34 and 7.11 with a mean rank score of 3.84, 3.44 and 2.72.

The mean score for colour of the cooked rice varied from 7.84 (*Aathira*) to 6.48 (*Ezhome-4*) with a mean rank score of 4.59 to 1.62. Control variety *Jyothi* obtained a mean score of 7.8 and a mean rank score of 4.91. *Kanchana*, *Aiswarya* and *Samyuktha* obtained a mean scores of 7.6, 7.37 and 6.55 with a mean rank scores of 4.22, 3.53 and 2.12.

The mean scores of colour in parboiled rice varied from 7.71 (*Aathira*) to 6.77 (*Ezhome-4*) with a mean rank score of 4.84 and 1.84 respectively. Control variety *Jyothi* obtained a mean score of 7.37 with a mean rank score of 3.72. Red rice varieties *Kanchana*, *Jyothi*, *Aiswarya* and *Samyuktha* obtained mean scores of 7.55, 7.37, 7.31 and 7 with a mean rank score of 4.44, 3.72, 3.62 and 2.53.

Among raw rice varieties the highest mean score for flavour was obtained in *Aiswarya* (7.77) with a mean rank score of 5.03. *Ezhome-4* obtained a lowest score of 6.68 with a mean rank score of 2.09. Control variety *Jyothi* and *Kanchana* obtained same mean score 7.26 with a mean rank score of 3.50 and 3.78 respectively. *Samyuktha* obtained a mean score of 6.84 with a mean rank score of 2.34.

Among parboiled red rice varieties the highest mean score for flavour was observed in *Kanchana* (7.8) and lowest was noticed in *Ezhome-4* (6.62) with a mean rank score of 5.06 and 1.78 respectively. Control variety *Jyothi* obtained a second highest mean score of 7.53 with a mean rank score of 4.38. Rice varieties *Aathira*, *Aiswarya* and *Samyuktha* obtained mean scores of 7.37, 7.24 and 6.91 with a mean rank scores of 3.97, 3.50 and 2.31.

The highest mean score for texture among raw rice was observed in control variety *Jyothi* (6.82) and lowest in *Samyuktha* (6.46) with a mean rank of 5.00 and 1.69 respectively. The other red rice varieties like *Kanchana*, *Aiswarya*, *Aathira* and *Ezhome-4* obtained a mean score of 6.53, 6.51, 6.50 and 6.91 with a mean rank scores of 4.09, 4.12, 3.38 and 2.72 respectively.

Table 7. Organoleptic qualities of table rice with raw and parboiled rice

Varieties	Mean rank scores											
	Appearance		Colour		Flavour		Texture		Taste		Over all acceptability	
	R	P	R	P	R	P	R	P	R	P	R	P
Jyothi	7.44 (4.41)	7.88 (4.59)	7.80 (4.91)	7.37 (3.72)	7.26 (3.50)	7.53 (4.38)	6.82 (5.00)	7.48 (4.56)	7.17 (3.62)	7.64 (4.19)	7.60 (4.31)	7.58 (4.19)
Aathira	7.24 (4.00)	7.80 (4.62)	7.84 (4.59)	7.71 (4.84)	7.51 (4.25)	7.37 (3.97)	6.50 (3.38)	7.31 (3.97)	7.37 (3.94)	7.66 (4.47)	7.44 (3.47)	7.73 (4.50)
Aiswarya	7.51 (4.59)	7.34 (3.44)	7.37 (3.53)	7.31 (3.62)	7.77 (5.03)	7.24 (3.50)	6.51 (4.12)	6.95 (2.72)	7.46 (4.19)	7.42 (3.16)	7.60 (3.94)	7.11 (2.84)
Ezhome-4	6.26 (1.44)	6.64 (1.78)	6.48 (1.62)	6.77 (1.84)	6.68 (2.09)	6.62 (1.78)	6.91 (2.72)	6.82 (2.50)	6.95 (2.91)	6.75 (2.16)	6.97 (2.41)	7.00 (2.62)
Kanchana	7.13 (3.56)	7.55 (3.84)	7.60 (4.22)	7.55 (4.44)	7.26 (3.78)	7.80 (5.06)	6.53 (4.09)	7.42 (4.22)	7.41 (4.06)	7.75 (4.62)	7.52 (3.21)	7.77 (4.91)
Samyuktha	6.86 (3.00)	7.11 (2.72)	6.55 (2.12)	7.00 (2.53)	6.84 (2.34)	7.00 (3.03)	6.46 (1.69)	6.91 (2.31)	6.71 (2.28)	6.97 (2.41)	6.71 (1.84)	6.84 (1.94)
Kendall's W value	**0.412****	**0.371****	**0.536****	**0.399****	**0.403****	**0.480****	**0.427****	**0.227****	**0.175****	**0.357****	**0.432****	**0.426****

Figures in parenthesis are mean rank scores

*significant at 1% level

R-Raw rice P-Parboiled rice

In parboiled rice varieties the highest mean score of 7.48 for texture was observed in control variety *Jyothi* with a mean rank score of 4.56. The lowest mean score was recorded in *Ezhome-4* (6.82) with a mean rank of 2.50. *Kanchana*, *Aathira*, *Samyuktha* and *Aiswarya* obtained a mean score of 7.42, 7.31, 7 and 6.95 with a mean rank scores of 4.22, 3.97, 3.03 and 2.72 respectively.

The highest mean score of 7.46 for taste among raw rice was observed in *Aiswarya* and lowest 6.71 was observed in *Samyuktha* with a mean rank score of 4.19 and 2.28 respectively. *Kanchana*, *Aathira* and *Ezhome-4* obtained a mean score of 7.41, 7.37 and 6.95 with a mean rank score of 4.06, 3.94 and 2.91 respectively. Control variety *Jyothi* obtained a mean score of 7.17 with a mean rank score of 3.62.

Among parboiled red rice varieties the highest mean score for taste was recorded in *Kanchana* (7.75) with a mean rank score of 4.62. The mean scores of 7.66, 7.64, 7.42, 6.97 and 6.75 are observed in varieties *Aathira*, *Jyothi*, *Aiswarya*, *Samyuktha* and *Ezhome-4* respectively. The mean rank scores of these varieties are 4.47, 4.19, 3.16, 2.41 and 2.16 respectively.

The highest mean score for overall acceptability among raw rice was noticed in *Jyothi* (7.60) with a mean rank score of 4.31 and *Aiswarya* (7.6) with a mean rank socore of 3.94. Lowest mean score for over acceptability was recorded in *Samyuktha* (6.71) with a mean rank score 1.84. The second highest value was observed in *Kanchana* (7.52) with a mean rank score of 3.21. Red rice varieties *Aiswarya*, *Aathira* and *Ezhome-4* obtained a mean score of 7.6, 7.44 and 6.97 respectively. The mean scores for these varieties are 3.94, 3.47 and 2.41 respectively.

The mean rank score for overall acceptability varied from 7.77 (*Kanchana*) to 6.84 (*Samyuktha*). Control variety *Jyothi* obtained a mean score of 7.58 with a mean rank score of 4.19. *Aathira*, *Aiswarya* and *Ezhome-4* obtained a mean score of 7.73, 7.11 and 7 with a mean rank score of 4.50, 2.84 and 2.62 respectively. The keeping quality of table rice prepared with both raw and

parboiled rice varieties were assessed and it was found to be acceptable after six hours.

4.2.2. Organoleptic evaluation of rice based products

42.2.2.1. Sensory qualities of *Idli* prepared with raw and parboiled rice

The fermented breakfast preparation *idli* was prepared with raw and parboiled rice varieties and the mean scores for different quality attributes are presented in Table 8. The highest mean score for appearance among raw rice varieties was recorded in *Aiswarya* (8.2) rice variety with a mean rank score of 4.60. The lowest mean score for appearance was noticed in *Samyuktha* (7.46) with a mean rank score of 1.97. *Idli* prepared with raw rice of *Aathira*, *Kanchana*, control variety *Jyothi*, and *Ezhome-4* obtained a mean scores of 7.95, 7.88, 7.88, and 7.82 with a mean rank scores of 3.87, 3.60, 3.57 and 3.40 respectively.

In parboiled rice varieties highest mean score for appearance was noticed in control variety *Jyothi* (8.20) with a mean rank score of 4.33. The varieties like *Kanchana*, *Ezhome-4*, *Samyuktha* and *Aathira* obtained a mean score of 8.17, 8.02, 7.88 and 7.84 with a mean rank score of 4.10, 3.97, 3.30 and 2.87. The lowest mean score was observed in *Aiswarya* (7.71) rice variety with a mean rank score of 2.43.

Mean score for colour of *idli* prepared with raw rice ranged from 8.00 (*Aiswarya*) to 7.42 (*Samyuktha*). Varieties like *Ezhome-4*, *Aathira*, *Jyothi* and *Kanchana* obtained a mean scores of 7.88, 7.82, 7.77 and 7.66 respectively. These varieties obtained a mean rank scores of 4.03, 3.70, 7.77 and 3.25 respectively.

The highest mean score for colour in parboiled rice varieties was observed in *Ezhome-4* (7.97) followed by *Aathira* (7.93), *Kanchana* (7.93), *Samyuktha* (7.88), *Aiswarya* (7.75) and control variety *Jyothi* (7.73). The mean rank scores of these varieties were found to be 3.77, 3.87, 3.80, 3.57, 3.03 and 2.97 respectively.

Idli prepared with raw rice of *Aiswarya* variety obtained a highest mean score for flavour that is 8.15 with a mean rank score of 4.60. The second highest

Jyothi

Aathira

Aiswarya

Ezhome-4

Kanchana

Samyuktha

Plate 6. *Idli* prepared with various raw rice varieties

Jyothi

Aathira

Aiswarya

Ezhome-4

Kanchana

Samyuktha

Plate 7. *Idli* prepared with various parboiled rice varieties

mean score for flavour was noticed in *Aathira* (8.02) rice variety with a mean rank score of 4.10. *Ezhome-4*, *Jyothi* and *Kanchana* obtained a mean rank score of 3.50, 3.57 and 2.63 with a mean score of 7.88, 7.86 and 7.66 respectively. *Samyuktha* rice variety obtained a lowest mean score of 7.66 with a mean rank score of 2.60.

The highest mean score of 8.11 for flavour of *idli* prepared with parboiled rice was noticed in control variety *Jyothi* with a mean rank score of 4.20. The second highest score was recorded in *Kanchana* (8.00) with a mean rank score of 3.70. *Aiswarya*, *Ezhome-4* and *Aathira* obtained a mean scores of 8.00, 7.97 and 7.86 with a mean rank score of 3.67, 3.57 and 2.93. The lowest mean score for flavour was observed in *Samyuktha* (7.84) rice variety with a mean rank score of 2.93.

In the case of texture among raw rice varieties, the mean scores varied from 7.71 (*Samyuktha*) to 8.35 (*Kanchana*). Varieties like *Aiswarya*, *Jyothi*, *Ezhome-4* and *Aathira* obtained a mean score of 8.02, 7.86, 7.84 and 7.80 with a mean rank scores of 4.27, 3.70, 3.63 and 3.10 respectively.

The mean scores for texture of *idli* prepared with parboiled rice ranged from 8.06 (*Kanchana*) to 7.8 (*Aathira*) with a mean rank of 4.10 and 2.77. Varieties like *Aiswarya*, *Ezhome-4*, *Jyothi* and *Samyuktha* obtained a mean scores of 7.97, 7.95, 7.93 and 7.86 with a mean rank score of 3.70, 3.57, 3.60 and 3.07 respectively.

The mean rank scores for taste of *idli* prepared with raw red rice varieties ranged from 8.04 (*Kanchana*) to 7.75 (*Ezhome-4*). The mean scores of 8.02, 7.93, 7.91 and 7.88 was noticed in *Aiswarya*, *Jyothi*, *Samyuktha* and *Aathira* varieties respectively. The mean rank scores of 3.77, 3.53, 3.63 and 3.30 were observed in these varieties.

In *idli* prepared with parboiled rice, the highest mean score for taste was observed in *Kanchana* (8.13) followed by *Aathira* (8.00), *Ezhome-4* (7.97), *Jyothi*

Table 8. Organoleptic qualities of *idli* with raw and parboiled rice

Varieties	Mean rank scores											
	Appearance		Colour		Flavour		Texture		Taste		Over all acceptability	
	R	P	R	P	R	P	R	P	R	P	R	P
Jyothi	7.88 (3.57)	8.20 (4.33)	7.77 (3.50)	7.73 (2.97)	7.86 (3.70)	8.11 (4.20)	7.86 (3.70)	7.93 (3.60)	7.93 (3.53)	7.95 (3.33)	7.97 (3.47)	7.71 (2.73)
Aathira	7.95 (3.87)	7.84 (2.87)	7.82 (3.70)	7.93 (3.87)	8.02 (4.10)	7.86 (2.93)	7.80 (3.10)	7.80 (2.77)	7.88 (3.30)	8.00 (3.43)	8.02 (3.90)	8.00 (4.03)
Aiswarya	8.20 (4.60)	7.71 (2.43)	8.00 (4.13)	7.75 (3.03)	8.15 (4.60)	8.00 (3.67)	8.02 (4.27)	7.97 (3.70)	8.02 (3.77)	7.91 (3.07)	8.02 (3.90)	7.88 (3.40)
Ezhome-4	7.82 (3.40)	8.02 (3.97)	7.88 (4.03)	7.97 (3.77)	7.88 (3.50)	7.97 (3.57)	7.84 (3.63)	7.95 (3.57)	7.75 (2.77)	7.97 (3.80)	7.93 (3.67)	7.91 (3.40)
Kanchana	7.88 (3.60)	8.17 (4.10)	7.66 (3.23)	7.93 (3.80)	7.66 (2.63)	8.00 (3.70)	8.42 (3.43)	8.06 (4.10)	8.04 (4.00)	8.13 (4.20)	8.04 (3.70)	8.08 (4.03)
Samyuktha	7.46 (1.97)	7.88 (3.30)	7.42 (2.40)	7.88 (3.57)	7.66 (2.60)	7.84 (2.93)	7.71 (2.87)	7.86 (3.27)	7.91 (3.63)	7.82 (3.17)	7.68 (2.57)	7.95 (3.40)
Kendall's W value	**0.251***	**0.187***	**0.131***	**0.052***	**0.196***	**0.079***	**0.077***	**0.065***	**0.058***	**0.061***	**0.109***	**0.075***

Figures in parenthesis are mean rank scores

*significant at 1% leve

lR-Raw rice P-Parboiled rice

(7.95), *Aiswarya* (7.91) and *Samyuktha* (7.82). The mean rank scores of these varieties found to be 4.20, 3.43, 3.80, 3.33, 3.07 and 3.17.

The mean rank scores for overall acceptability of *idli* was noticed in *Kanchana* (8.04) and the lowest was in *Samyuktha* (7.68) with a mean rank scores of 3.70 and 2.57. Among different raw red rice varieties, the second highest mean score for overall acceptability was recorded in *Aiswarya* (8.02) followed by *Aathira* (8.02), *Jyothi* (7.97) and *Ezhome-4* (3.67). These varieties obtained a mean rank scores of 3.90, 3.90, 3.47 and 3.67 respectively.

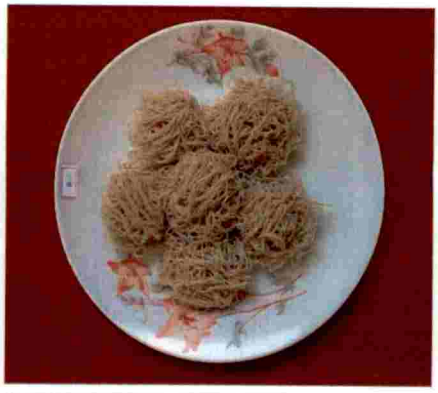
The overall acceptability for *idli* prepared with parboiled rice obtained mean scores ranged from 8.08 (*Kanchana*) to 7.71 (*Jyothi*). The second highest mean score was observed in rice variety *Aathira* (4.03) followed by *Samyuktha* (7.95), *Ezhome-4* (7.91) and *Aiswarya* (7.88). The mean scores of these varieties were 4.03, 4.03, 3.40, 3.40, 3.40 and 2.73. The keeping quality of *idli* prepared with both raw and parboiled rice varieties were assessed and it was found to be acceptable after six hours.

4.2.2.2. Sensory qualities of *Idiyappam* prepared with raw and parboiled rice flour

The mean scores and mean rank scores obtained for different quality attributes of *idiyappam* prepared with raw rice flour are presented in Table 9. The mean scores for appearance of *idiyappam* prepared with raw rice flour ranged from7.24 (*Aathira*) to 8.11 (*Ezhome-4*) with a mean rank score of 2.40 and 5.00. Varieties like *Samyuktha*, *Aiswarya*, *Kanchana* and *Jyothi* obtained a mean scores of 7.88, 7.73, 7.68 and 7.46 with a mean rank scores of 3.90, 3.43, 3.33 and 2.93.

The mean scores for appearance of *idiyappam* prepared with parboiled rice flour varied from 6.91 (*Aathira*) to 8.13 (*Ezhome-4*) with a mean rank scores of 1.17 and 4.67. Varieties like *Kanchana*, *Samyuktha*, *Aiswarya* and control variety *Jyothi* obtained a mean scores of 8.00, 7.97, 7.91 and 7.62 with a mean rank scores of 4.13, 4.13, 3.80 and 3.10 respectively.

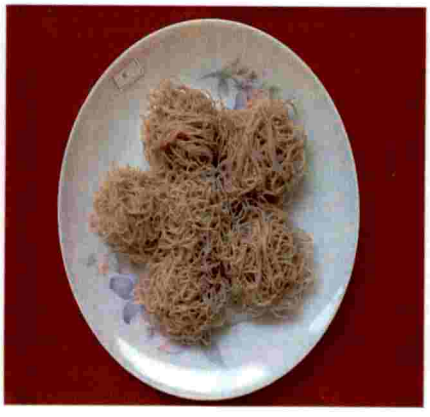
Jyothi



Aathira

Aiswarya

Ezhome-4



Kanchana

Samyuktha

Plate 8. *Idiyappam* prepared with various raw rice varieties

Jyothi

Aathira

Aiswarya

Ezhome-4

Kanchana

Samyuktha

Plate 9. *Idiyappam* prepared with various parboiled rice varieties

The highest mean scores for colour of *idiyappam* was observed in *Samyuktha* (8.15) rice variety with a mean rank score of 4.80. It was followed by *Ezhome-4* (8.02), *Jyothi* (7.73), *Aiswarya* (7.62), *Kanchana* (7.51) and *Aathira* (7.06) with a mean rank scores of 4.40, 3.57, 3.60, 2.93 and 1.70.

The highest mean score for colour of *idiyappam* prepared with parboiled rice flour was observed in *Ezhome-4* (8.26) and followed by *Samyuktha* (8.13), *Aiswarya* (7.97), *Jyothi* (7.68), *Kanchana* (7.55) and *Aathira* (7.06). The mean scores of these varieties are 4.87, 4.23, 4.07, 3.57, 2.80 and 1.47 respectively.

For flavour of *idiyappam* prepared with raw rice flour, the highest mean score was observed in *Samyuktha* (8.11) and the lowest was in *Aathira* (6.97) rice vaiety with a mean rank scores of 4.80 and 1.87. Varieties like *Ezhome-4*, *Aiswarya*, *Kanchana* and *Jyothi* obtained a mean scores of 8.06, 7.8, 7.75 and 7.53 with a mean rank scores of 4.40, 3.67, 3.40 and 2.97.

In parboiled rice varieties the highest mean score for flavour was observed in *Ezhome-4* (8.15) with a mean rank score of 4.73. It was followed by *Samyuktha* (8.00), *Jyothi* (7.91), *Aiswarya* (7.86), *Kanchana* (7.75) and *Aathira* (6.88) with a mean rank scores of 4.30, 3.73, 3.63, 3.27 and 1.33.

The highest mean score for texture of *idiyappam* prepared with raw rice flour was observed in *Ezhome-4* (8.13) rice variety with a mean rank score of 4.73. Control variety *Jyothi* obtained a mean score of 7.82 with a mean rank score of 3.83. *Aiswarya*, *Samyuktha*, *Kanchana* and *Aathira* obtained a mean scores of 7.8, 7.77, 7.71 and 7.12 with a mean rank scores of 3.57, 3.80, 3.43 and 1.63.

The mean scores for texture of *idiyappam* prepared with parboiled rice flour was the highest in *Samyuktha* (8.22) and the lowest was recorded in *Aathira* (6.95) with a mean rank score of 4.93 and 1.30. Varieties like *Ezhome-4*, *Aiswarya*, *Jyothi*, and *Kanchana* obtained a mean scores of 8.17, 7.84, 7.71 and 7.71 with a mean rank scores of 4.70, 3.57, 3.33 and 3.17.

Table 9. Organoleptic qualities of *idiyappam* prepared with raw and parboiled rice flour

Varieties	Mean rank scores											
	Appearance		Colour		Flavour		Texture		Taste		Over all acceptability	
	R	P	R	P	R	P	R	P	R	P	R	P
Jyothi	7.46 (2.93)	7.62 (3.10)	7.73 (3.57)	7.68 (3.57)	7.53 (2.97)	7.91 (3.73)	7.82 (3.83)	7.71 (3.33)	7.75 (3.57)	8.06 (4.03)	7.75 (4.13)	8.02 (4.23)
Aathira	7.24 (2.40)	6.91 (1.17)	7.06 (1.70)	7.06 (1.47)	6.97 (1.87)	6.88 (1.33)	7.12 (1.63)	6.95 (1.30)	7.17 (2.10)	7.04 (1.27)	7.42 (2.57)	7.04 (1.30)
Aiswarya	7.73 (3.43)	7.91 (3.80)	7.62 (3.60)	7.97 (4.07)	7.80 (3.67)	7.86 (3.63)	7.80 (3.57)	7.84 (3.57)	8.00 (4.00)	7.93 (3.43)	7.64 (3.20)	7.82 (3.30)
Ezhome-4	8.11 (5.00)	8.13 (4.67)	8.02 (4.40)	8.26 (4.87)	8.06 (4.47)	8.15 (4.73)	8.13 (4.73)	8.17 (4.70)	7.93 (4.50)	8.24 (4.83)	8.08 (4.53)	8.22 (4.73)
Kanchana	7.68 (3.33)	8.00 (4.13)	7.51 (2.93)	7.55 (2.80)	7.75 (3.40)	7.75 (3.27)	7.71 (3.43)	7.71 (3.17)	7.42 (2.43)	7.44 (3.33)	7.53 (2.50)	7.75 (3.33)
Samyuktha	7.88 (3.90)	7.97 (4.13)	8.15 (4.80)	8.13 (4.23)	8.11 (4.63)	8.00 (4.30)	7.77 (3.80)	8.22 (4.93)	7.95 (4.40)	8.06 (4.10)	7.93 (4.07)	8.04 (4.10)
Kendall's W value	**0.257***	**0.544***	**0.367***	**0.447***	**0.327***	**0.437**	**0.339***	**0.514***	**0.343***	**0.476***	**0.235***	**0.466***

Figures in parenthesis are mean rank scores

*significant at 1% level

R-Raw rice P-Parboiled rice

For taste, the highest mean score was noticed in rice variety *Samyuktha* (7.95) with a mean rank score of 4.40. The lowest mean score was observed in *Aathira* (7.17) variety with a mean rank score of 2.10. Other red rice varieties like *Ezhome-4*, *Aiswarya*, *Jyothi* and *Kanchana* obtained a mean scores of 7.93, 7.80, 7.75 and 7.42 respectively. The mean rank scores of these varieties are 4.50, 4.00, 3.57 and 2.43 respectively.

In parboiled rice varieties, the highest mean score for taste was observed in *Ezhome-4* (8.24) and the lowest was in *Aathira* (7.04) with a mean rank scores of 4.83 and 1.27. *Jyothi*, *Samyuktha*, *Aiswarya* and *Kanchana* obtained a mean scores of 8.06, 8.04, 7.93 and 7.84 with a mean rank scores of 4.03, 4.10, 3.43 and 3.33 respectively.

The overall acceptability for *idiyappam* prepared with raw rice flour obtained the highest mean score of 8.08 in *Ezhome-4* rice variety and was followed by 7.95 (*Jyothi*), 7.93 (*Samyuktha*), 7.64 (*Aiswarya*), 7.53 (*Kanchana*) and 7.42 (*Aathira*). The mean rank scores of these varieties are 4.53, 4.13, 4.07, 3.20, 2.50 and 2.57 respectively.

The highest mean score for overall acceptability of *idiyappam* prepared with parboiled rice flour was noticed in *Ezhome-4* (8.22) followed by *Samyuktha* (8.04), *Jyothi* (8.02), *Aiswarya* (7.82), *Kanchana* (7.75) and *Aathira* (7.04). The mean rank scores of these varieties are 4.73, 4.10, 4.23, 3.30, 3.33 and 1.30 respectively. The keeping quality of *idiyappam* prepared with both raw and parboiled rice varieties were assessed and it was found to be acceptable after six hours.

DISCUSSION

5. DISCUSSION

The results of the study entitled 'Quality evaluation of KAU red rice (*Oryza sativa* L.) varieties' are discussed under the following headings.

5.1. Quality evaluation of raw rice and parboiled rice

5.1.1. Physical qualities of raw rice and parboiled rice

5.1.2. Physical qualities of raw rice flour and parboiled rice flour

5.1.3. Cooking qualities of raw rice and parboiled rice

5.1.4. Nutritional qualities of raw rice and parboiled rice

5.2. Acceptability of traditional food products

5.2.1. Organoleptic evaluation of table rice

5.2.2. Organoleptic evaluation of rice based products

5.1. Quality evaluation of raw rice and parboiled rice

5.1.1. Physical qualities of raw rice and parboiled rice

Quality traits highly influence consumption and trade of rice and rice products and are vital for the performance evaluation of different rice cultivars. Physical properties of rice like milling per cent, head rice recovery, thousand grain weight, volume weight, grain shape and size were evaluated in both raw and parboiled samples of different rice varieties. Milling yield is one of the most important criteria of rice quality.

The milling per cent of raw red rice varieties were in the range of 62.76 (*Aathira*) per cent to 76 (*Ezhome-4*) per cent. The milling per cent of raw and parboiled rice varieties are presented in Figure 1. In the present study, milling per cent observed for control variety *Jyothi* was 65 per cent. In line with this, Vanaja and Babu (2006) and Sathyan (2012) observed a milling recovery of 64.2 per cent

and 66.60 per cent respectively in *Jyothi*. A slightly higher milling per cent of 73.80 was observed in *Jyothi* by Chandhni (2015). 94

Government of India (2013) reported that Kaipad rice varieties Ezhome-1, Ezhome2, Kuthiru, Orkamaya had a milling per cent of 76.9 per cent, 75.3 per cent, 74.8 per cent and 75.1 per cent respectively. According to Chandhni (2015) Ezhome-1 and Ezhome-2 obtained a milling per cent of 72.03 per cent and 77.83 per cent respectively. In the present study, raw *Kanchana* and *Samyuktha* obtained a milling per cent of 68.76 per cent and 72.21per cent. Francies *et al.* (2013) observed a slightly higher milling recovery of 70 per cent and 74 per cent in *Samyuktha* and *Kanchana* rice varieties.

Rajesh (2016) indicated that *Aiswarya*, *Kanchana* and *Samyuktha* had a milling per cent of 62.3 per cent, 66.9 per cent and 65.67 per cent respectively which were lower than the observations in the present study.

The milling per cent of parboiled rice varieties were comparatively higher than that of raw rice varieties. In parboiled samples, the milling per cent was in the range of 67.66 (*Aiswarya*) per cent to 75 (*Kanchana*) per cent. Lakshmi (2011) observed a milling per cent of 72.10 in parboiled *Jyothi* variety. Akther *et al.* (2015) observed a milling recovery of 72.5 per cent in parboiled rice. According to George (2012), parboiling improves milling quality due to the hardness imparted to kernels because of gelatinization of starch. It was found that due to swelling of starch, the cracks, incomplete filling and chalkiness are completely healed. Degree of rice starch gelatinization was increased from two to sixty per cent and the percentage of kernel breakage decreased from seven to one per cent in a linear manner on parboiling (Elbashir, 2005).

Head rice recovery depends on the grain type, chalkiness, cultivation process and drying condition. In the present study, head rice recovery in raw samples varied from 59.15 per cent (*Ezhome-4*) to 49.32 per cent (*Aiswarya*) and is presented in Figure 2. In line with the present study, Chandhni (2015) observed a head rice recovery of 49.48 per cent and 55.49 per cent in Ezhome-2 and

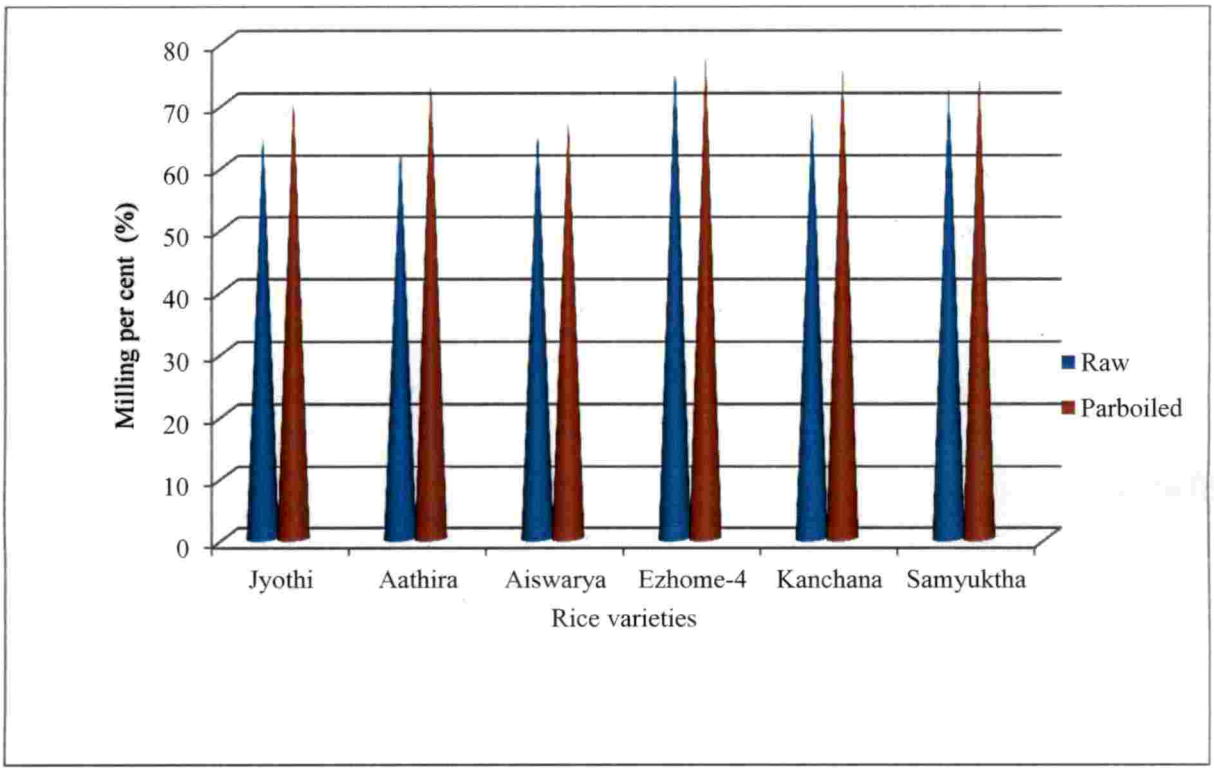


Fig. 1. Milling per cent of raw and parboiled rice varieties

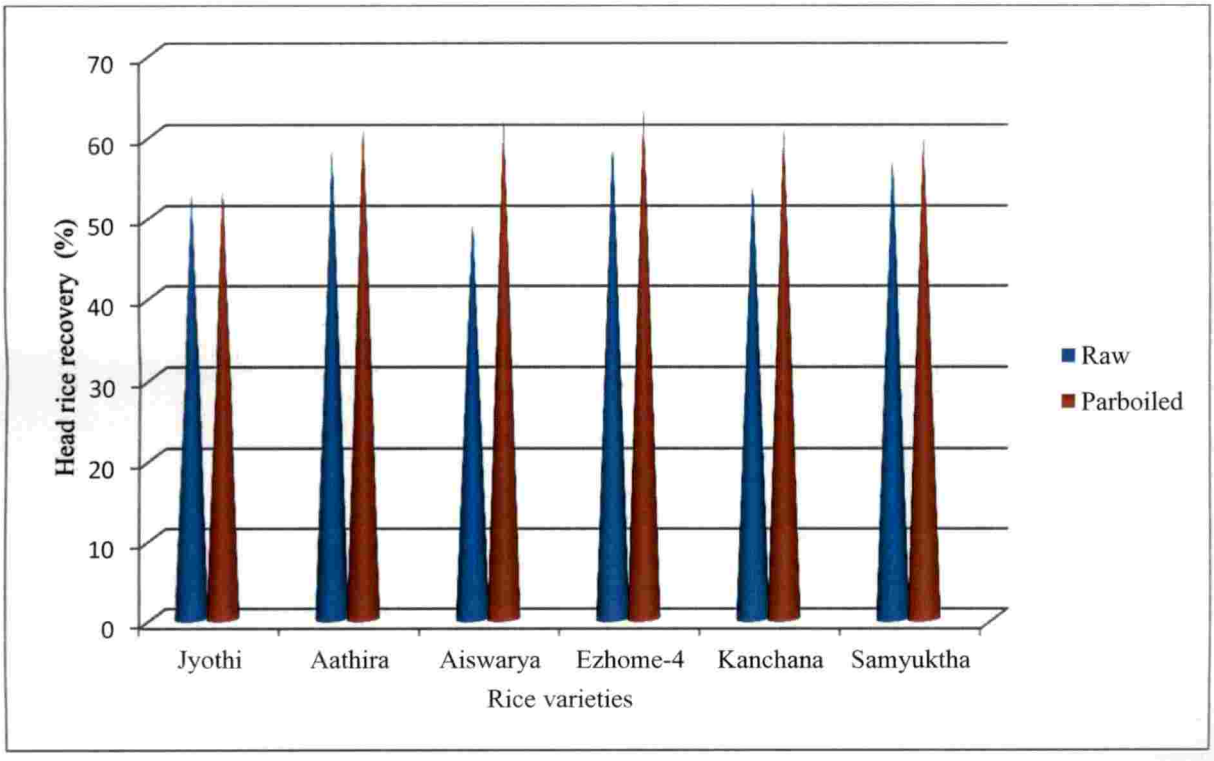


Fig. 2. Head rice recovery of raw and parboiled rice varieties

Ezhome-1 respectively. Vanaja *et al.* (2003) observed slightly higher head rice recovery of 62.6 per cent in Ezhome-3. A report by Government of India (2013) indicated head rice recovery of 62 and 63 per cent in Ezhome-1 and Ezhome-2 respectively which was higher than the observations in the present study.

In the present study, a head rice recovery of 54.26 per cent and 57.11 per cent was observed in *Kanchana* and *Samyuktha* variety respectively. In line with this, Rajesh (2016) observed a head rice recovery of 56 and 52.34 per cent in *Kanchana* and *Samyuktha* varieties. But a slightly higher head rice recovery of 74 per cent and 69 per cent respectively was observed in *Kanchana* and *Samyuktha* varieties by Francies *et al.* (2013). Head rice recovery is an inherited trait but the factors like temperature and humidity, grain size, grain shape, hardness, moisture content and harvest and storage conditions may bring variations in head rice recovery (Rani *et al.*, 2006).

The present study revealed that the parboiled samples gives higher head rice recovery compared to raw samples. In parboiled samples, head rice recovery was in the range of 53.66 (*Jyothi*) per cent to 62.86 (*Ezhome-4*) per cent. Miah *et al.* (2002) also observed a large reduction in fissured grains in parboiled samples of rice as compared to non-parboiled. This is due to the fact that parboiling fills the void spaces in the endosperm and hence the cracks within the grains are cemented, making the grain harder leading it to less breaking percentage.

Sareepuang *et al.* (2008) reported a significant increase in head rice recovery after parboiling in brown rice. This improvement was caused by stronger structure of rice starch as a result of gelatinisation process. Ibukun (2008) found that parboiling for 45 minutes resulted in minimum amount of breakages of 19.5 per cent. Verma *et al.* (2012) reported less breakage and higher head rice recovery in a range of 47-55 per cent in bold and short grains. Ravi *et al.* (2012) reported a head rice recovery of 40.65 and 72.15 per cent in raw and parboiled samples of Salem samba variety.

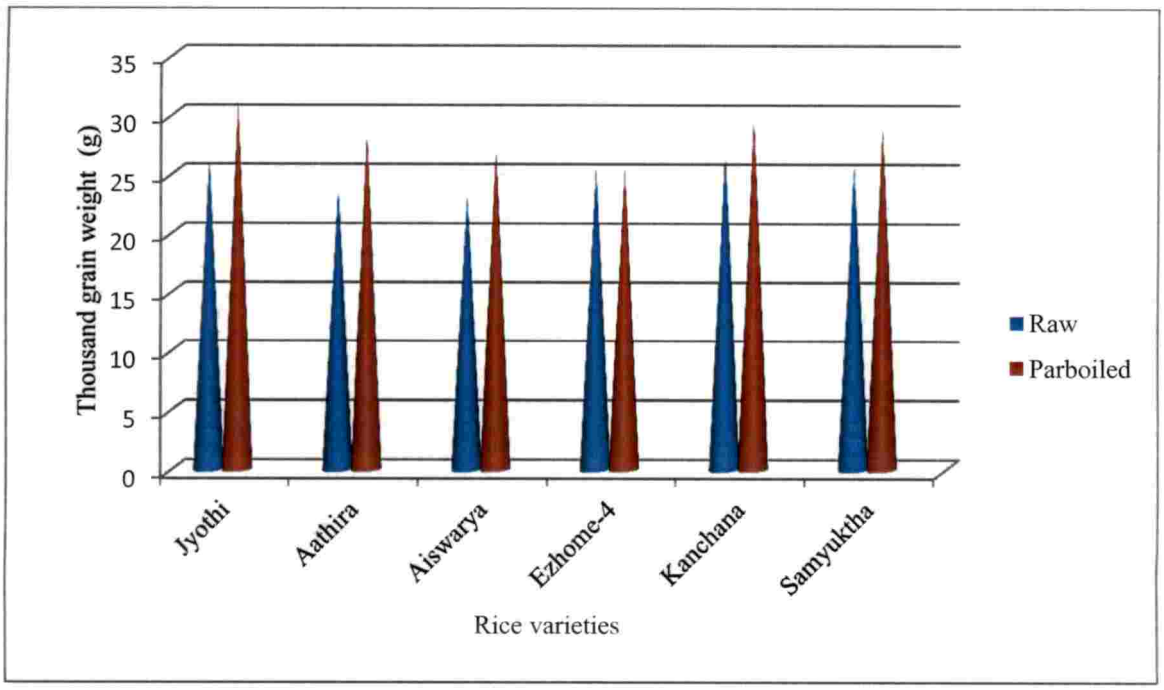


Fig. 3. Thousand grain weight of raw and parboiled rice varieties

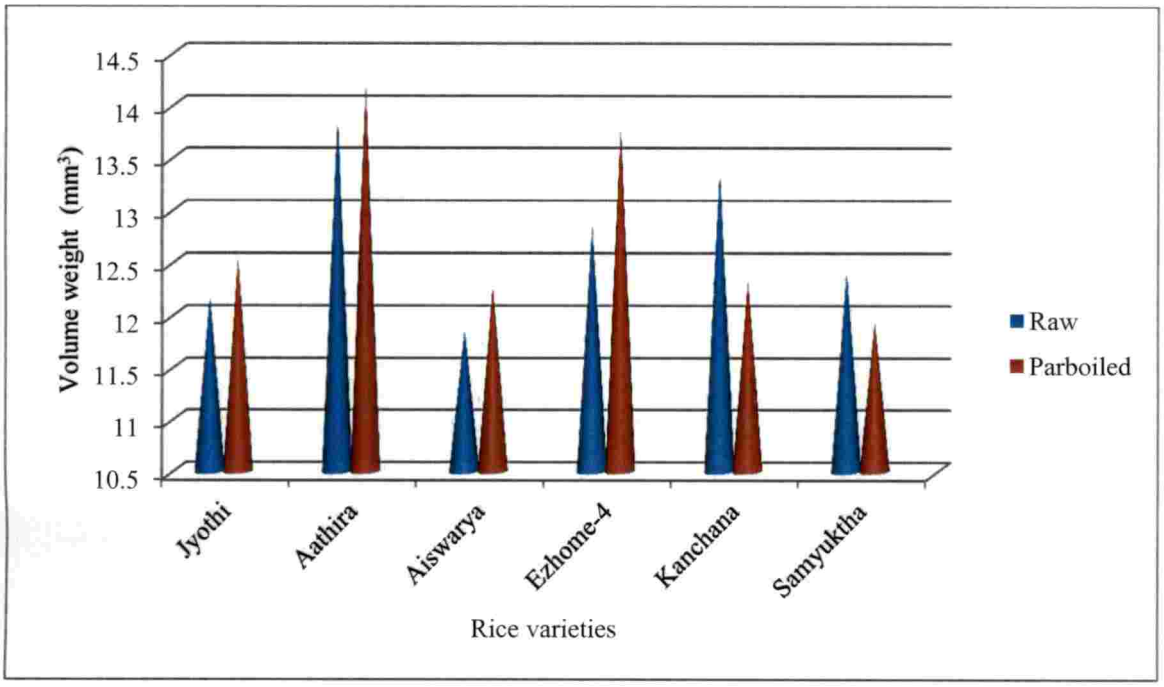


Fig. 4. Volume weight of raw and parboiled rice varieties

Grain weight highly influences grain yield and effects cooking and sensory qualities of rice. Thousand grain weight of raw rice varieties were in the range of 22.96 per cent (*Aiswarya*) to 26.64 per cent (*Kanchana*). In the present study, a thousand grain weight of 26.12g was observed in *Jyothi* but a lower value of 19.98g was reported in *Jyothi* by Chandhni (2015). *Ezhome-4* observed a thousand grain weight of 25.41g in present study. In line with this, Government of India (2013) reported that Kaipad rice varieties had a thousand grain weight of 28.3g and 25.6g for Ezhome-1 and Ezhome-2 respectively.

Kwarteng *et al.* (2003) reported a thousand grain weight of 20 to 30 g is acceptable in rice. Brown rice varieties like IR-8, Govinda and Sharbati had thousand grain weight of 24.02, 18.25 and 14.31 g respectively (Gujral and Kumar, 2003). Ravi *et al.* (2012) observed that the grain weight of paddy and brown rice were found to be 16.9 g and 13.5 g Salem samba varieties. A thousand grain weight of 22.52g, 23.19g, 22.60g, 22.78g, 22.76g, 22.61g, 22.55g, 23.09g, 21.37g and 22.76g was observed in rice varieties Jayathi, Onam, Tulasi, Parambuvattan, Thekkencheera, Mancompu 519, Annapoorna, Thottacheera, Karuthadukkan, Chomala and Mo-7 respectively (Saini *et al.*, 2013).

In the present study, the thousand grain weight in parboiled samples was observed in the range of 31.01g (*Jyothi*) to 25.33g (*Ezhome-4*). Lakshmi (2011) reported a thousand grain weight of 25.56 g in parboiled *Jyothi* variety. According to Itagi and Singh (2015) thousand grain weight was increased by 7 per cent after parboiling.

In the present study, *Jyothi* observed a volume weight of 12.16 mm^3. In line with this Chandhni (2015) observed a volume weight of 12.33mm^3 in *Jyothi*. In the present study, *Ezhome-4* obtained a volume weight of 12.83mm^3. In line with this, Chandhni (2015) reported a volume weight of 12.96 and 12.81mm^3 in Ezhome-1 and Ezhome-2 respectively. In parboiled rice varieties, volume weight was noticed in the range of 14.17 mm3 (*Aathira*) to 11.93 mm3 (*Samyuktha*).

Grain shape was determined by considering the L/B ratio of rice. In the present study, the highest grain length was observed in control variety *Jyothi* (9.45 mm) and the lowest was in *Ezhome-4* (5.63 mm). Vanaja and Babu (2006) noticed a grain length of 9.09 mm, 8.84 mm and 9.16 mm in rice varieties Vyttila-2, Vyttila-3 and Vyttila-4 respectively. The author also observed a higher grain length of 9.73 mm and 8.55 mm in *Jyothi* and Matta Triveni rice varieties. In line with the present study, Chandhni (2015) observed a grain length of 4.95 mm in Ezhome1 and 4.33mm in Ezhome-2. In contrast to this, Government of India (2013) reported a higher grain length of 8.3 mm, 8.1 mm, 8.7 mm and 8.9 mm in Kaipad rice varieties Ezhome-1, Ezhome-2, Kuthiru and Orkayama respectively.

The highest grain length in parboiled rice was in the range of 9.22mm (*Jyothi*) to 5.60mm (*Ezhome-4*). Kotagi *et al.* (2015) observed a grain length of 6.37 mm and 6.24 mm in parboiled Jaya and MTU1001 respectively. Parboiled *Jyothi* and IR-64 obtained a grain length of 8.9 mm and 9.6 mm respectively (Itagi and Singh, 2015). Parboiled rice kernel has a shorter length and broader breadth when compared with the non-parboiled rice sample (Otegbayo *et al.*, 2001).

The grain width of raw rice varieties was in the range of 2.08 mm (*Ezhome-4*) to 2.89 mm (*Jyothi*). A lower grain width of 1.84 mm and 1.21 mm was observed in Ezhome-1 and Ezhome-2 (Meena *et al.*, 2010). Kaipad rice varieties Ezhome-1, Ezhome-2, Kuthiru and Orkayama had grain width of 3.0 mm, 3.0 mm, 3.3 mm and 3.2 mm respectively (Government of India, 2013). Saini *et al.* (2013) reported a lower grain width of 1.75 mm, 1.98 mm, 1.97 mm, 1.30 mm, 1.56 mm in the rice varieties Jayathi, Onam, Tulasi, Parambuvattan, Thekkancheera respectively.

In the present study, the grain width of parboiled rice varieties ranged from 3.16 mm (*Jyothi*) to 2.29 mm (*Ezhome-4*). Itagi and Singh (2015) reported a grain width of 2.7 mm and 3.0 mm in parboiled IR-64 and *Jyothi* rice varieties. Rebeira *et al.* (2014) observed a grain width of 2.26 mm in Pokkali rice variety.

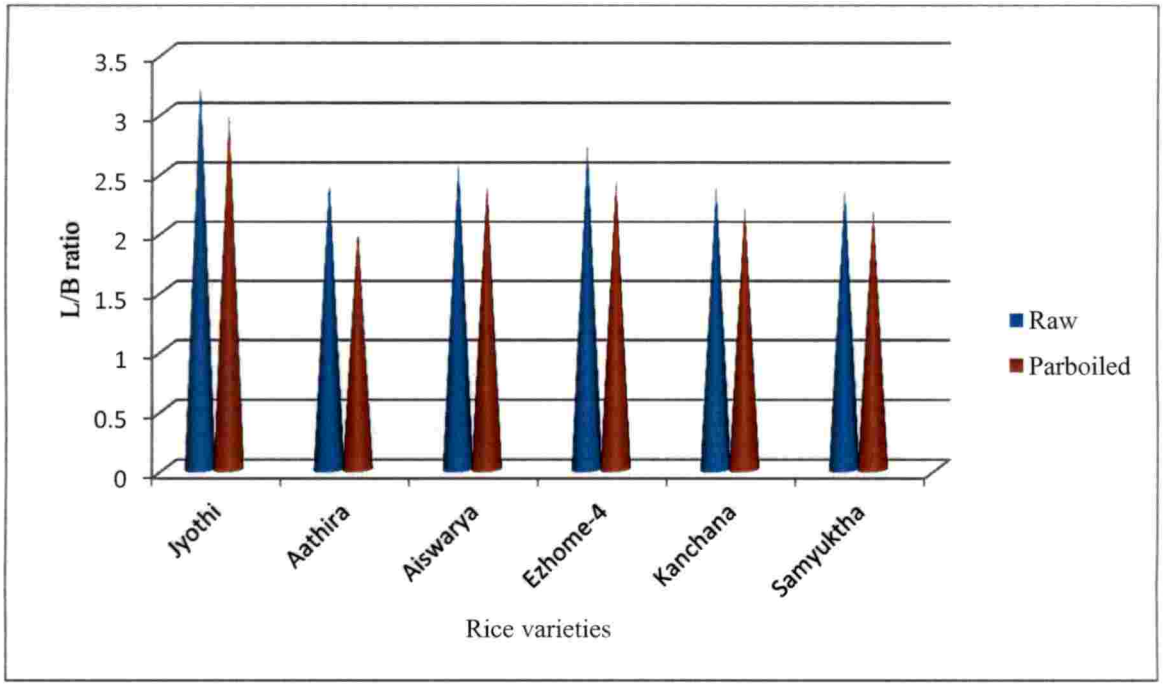


Fig. 5. L/B ratio of raw and parboiled rice varieties

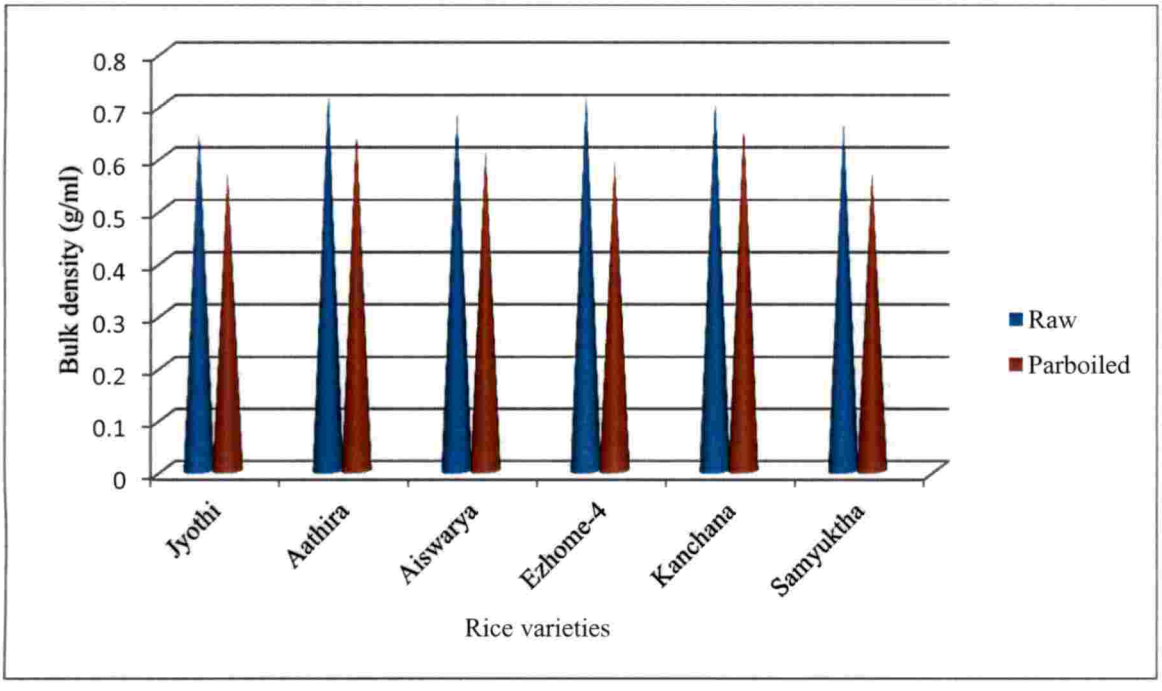


Fig. 6. Bulk density of raw and parboiled rice flour

Santhi and Vijayakumar (2014) reported a grain width of 3.00 mm and 3.04 mm in raw and parboiled Kavun rice variety.

According to Rather *et al.* (2016) cooking and eating qualities of rice are strongly influenced by shape and width of grains, hence determining the shape and width of grains is essential. In the present study, the L/B ratio of raw rice varieties ranged between 2.34 (*Aathira*) to 3.42 (*Jyothi*). According to Rebeira *et al.* (2014) the L/B ratio of pokkali rice variety was 2.52. Chandhni (2015) observed a L/B ratio of 2.3 and 3.59 in Ezhome-1 and Ezhome-2 respectively. Itagi and Singh (2015) reported that raw and parboiled *Jyothi* variety showed a L/B ratio of 3.6 and 3.8 respectively. According to Rajesh (2016) the L/B ratio of *Aiswarya*, *Kanchana* and *Samyuktha* was 3.47, 4.62 and 3.96 respectively. Francies *et al.* (2013) observed L/B ratio of 2.11 and 2.73 in *Samyuktha* and *Kanchana* rice variety respectively.

5.1.2. Physical qualities of raw and parboiled rice flour

Bulk density is an important physical property of milled rice, which depends on grain type, moisture content, kernel length and additional physical properties such as kernel shape and dimensional characteristics (Fan *et al.*, 1998). Rate of heat and mass transfer during aeration and drying depends upon density values of grains and it also useful in sizing grain hoppers and storage facilities (Rather *et al.*, 2016). In the present study, the highest bulk density of 0.72 was observed in *Ezhome-4*. According to Sathyan (2012) and (Lakshmi, 2011) bulk density of 0.84g/ml was noticed in rice flour of *Jyothi* variety. According to Chandhni (2015) bulk density and water uptake are significantly correlated. In the present study, the highest bulk density was observed in *Ezhome-4* which showed the higher water uptake also. According to Yadav and Jindal (2007) bulk density of Indian rice cultivars varied between 0.83 to 0.92g/ml.

In the present study lower bulk density was observed in parboiled samples. According to Saeed *et al.* (2011) parboiling decreases the bulk density of rice flour. The author also reported that the parboiled Super Basmati have a bulk

density of 0.74g/ml. The decrease in bulk density might be due to the decrease in dietary fibre by replacing the starch content during soaking and parboiling (El-Hady *et al.*, 1998). Islam *et al.* (2012) observed a bulk density of 0.85 g/ml in parboiled brown rice flour. Sona masuri and IR8 have a bulk density of 0.81 and 0.79 g/ml respectively (*Kanchana et al.*, 2012).

The water absorption index measures the amount of water absorbed by starch and can be used as an index of gelatinization (Morsy *et al.*, 2015). In the present study, water absorption index in raw samples ranged between 22.46 (*Samyuktha*) to 25.61 (*Aiswarya*). The difference in water absorption index may be due to the difference in amylose content of rice varieties. According to Sathyan (2012), water absorption index of raw *Jyothi* variety was 22.07. Mir and Bosco (2013) observed a water absorption index of 21.5 and 24.1 in raw brown rice varieties. According to Chandhni (2015) water absorption index of red rice varieties like Ezhome-1, Vaishak, Ezhome-2, Prathyasha, Vyttila-8, *Jyothi* and Uma are 23.78, 22.67, 23.74, 23.21, 22.98, 25.46 and 25.45 respectively.

In the present study, a lower water absorption index in parboiled samples ranging between 23.71 (*Aathira*) to 22.04 (*Ezhome-4*) was observed. According to Parnsakhorn and Noomhorm (2008) decrease in water absorption index of parboiled rice may be due to the modification of starch granules by heating and parboiling process. Therefore, starch structure becomes stronger and grain get hardened and hence water penetration is poor. According to Chang and Yang (1992) thermal processing decreases the water absorption index because starch becomes less easily solubilized. Lakshmi (2011) observed a water absorption index of 17.60 in parboiled *Jyothi* variety. According to Jamal *et al.* (2016) the difference in water absorption index of rice flour may be due to various factors such as methods of milling, level of starch damaged and processing temperature.

Water solubility index is related to the amount of soluble solids which is often used as an indication of degradation of starch molecules and dextrinisation (Silva *et al.*, 2009). In the present study, water solubility index is in the range of

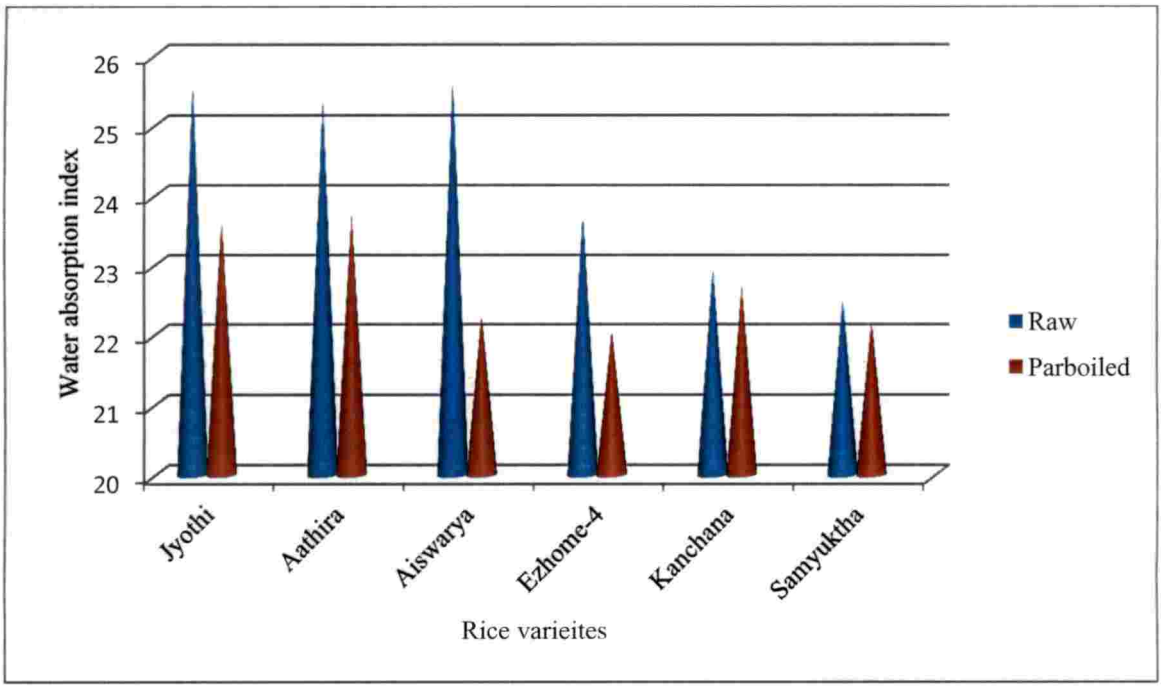


Fig. 7. Water absorption index of raw and parboiled rice flour

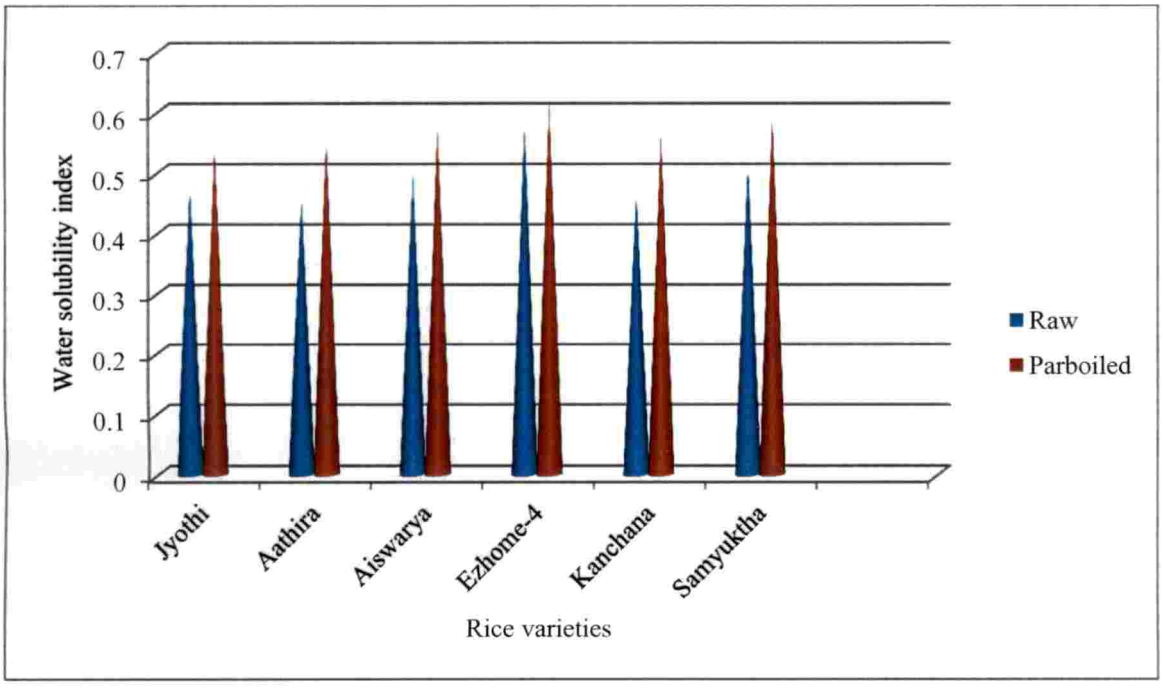


Fig. 8. Water solubility index of raw and parboiled rice flour

0.45 (*Aathira*) to 0.57 (*Ezhome-4*). In *Jyothi*, water solubility index of 0.47 was observed but a lower water solubility index of 0.20 was noticed in raw rice flour of *Jyothi* variety by Sathyan (2012). Chandhni (2015) observed a water solubility index of 0.34, 0.42, 0.49 0.55, 0.60, 0.61 and 0.73 in Ezhome-1, Uma, *Jyothi*, Prathyasha, Ezhome-2, Vaishak and Vyttila-8 respectively.

In the present study, water solubility index of parboiled samples was in the range of 0.54 (*Jyothi*) to 0.61 (*Ezhome-4*). According to Mir and Bosco (2013) parboiling increases the water solubility index which may be due to the more damaged starch present in parboiled rice flour to imbibe and hold more water. The factors which affects water solubility are the presence of protein, starch and lipid complex which reduces solubility index. According to Jamal *et al.* (2016) increase in water solubility index after parboiling may be due to the degradation of starch granules after parboiling.

According to Philpot *et al.* (2005) retrogradation in rice is a trait that describes the hardening of cooked rice after storage or cooling and it has significant implications for many consumers of rice. Retrogradation plays an important role in forming consumers utility of food products. It is usually described as recrystallization during storage after starch pasting (Zielinska and Fortuna, 2010). In the present study, the low syneresis in raw rice flour after 12th day was observed in control variety *Jyothi* and the highest syneresis was observed in *Samyuktha*. Difference in Retrogradation is might be due to differences in molecular properties of the amylopectin from each cultivar (Perdon *et al.*, 1999). Varieties having amylose content of 18-22 per cent had percentage retrogradation of 30-40 in a period of 7 days for six rice varieties of Thailand (Thumrongchote *et al.*, 2012).

The highest syneresis in parboiled varieties was observed in *Samyuktha* and the lowest was in *Aathira*. In the present study, parboiled rice flour shows higher synersis than raw rice flour. Philpot *et al.* (2005) reported that the degree of retrogradation was determined by the availability of long chain amylose. Amylose

tends to degrade after heat treatment it results the increase in syneresis percentage in parboiled rice flour (Manful *et al.*, 2008). According to Lakshmi (2011) parboiling decreases the amylose content it results higher retrogradation of rice flour. Rewthong *et al.* (2011) reported that retrograded starch formed during the freezing or cooling process could be destroyed after drying.

5.1.3. Cooking qualities of rice varieties

Gelatinization temperature positively determines the cooking time of rice. In the present study, *Samyuktha* obtained low gelatinization temperature *Jyothi*, *Aiswarya*, *Ezhome-4*, *Kanchana* and *Aathira* had intermediate gelatinization temperature. The differences in gelatinization temperature could be due to the environmental conditions such as temperature during ripening (IRRI, 2004). Higher gelatinization temperature or lower alkali spreading score was an indicative of a more crystalline structure and provided more resistance to water penetration and swelling in rice kernels (Yadav and Jindal, 2007).

In the present study, intermediate gelatinization temperature was observed in all parboiled varieties. According to Taghinezhad *et al.* (2016) rice moisture content during soaking and extent of heating during steaming increase the degree of starch gelatinization. Cruz and Khush (2000) reported that all Indian varieties that have intermediate gelatinization temperature are either intermediate or high in amylose content.

Cooking time is an important quality parameter of cooked rice, which varies with the cooking method and the processing conditions of rice. The cooking time taken by the rice varieties varied from 21 minutes (*Aiswarya*) to 27 minutes (*Ezhome-4*) in raw samples. According to Yadav *et al.* (2007) cooking time in the range of 16.50 to 18.30 minutes in Indian rice cultivars. Nandini (1995) observed a cooking time of 37 minutes in *Jyothi* variety. Rice cultivars with higher amylose content required less cooking time (Kadan *et al.*, 1997). In line with this, *Aiswarya* variety, which is having a higher amylose content which was obtained a lower cooking time. Meena *et al.* (2010) observed a cooking time

of 16, 20 and 19 minutes in rice varieties Pusa Basmati, IET 19228, IET 18675 respectively. Cooking time of 49 and 45 minutes was observed in white and brown raw rice varieties respectively (Otegbayo *et al.*, 2014). According to Raghuvanshi *et al.* (2017) cooking time is in the range of 30 to 40 minutes in Indian rice cultivars.

On parboiling, cooking time of rice varieties increased varying from 31.66 minutes (*Kanchana*) to 37 minutes (*Aiswarya*). Bradbury *et al.* (1984) reported that parboiled rice has longer cooking time due to the strong cohesion between the endosperm cells which are tightly packed. Nandini (1995) reported that optimum cooking time of 46 minutes was reported in parboiled rice of *Jyothi* variety. Kandathil (1997) reported that the optimum cooking time for parboiled rice was 31 to 66 minutes. Otegbayo *et al.* (2014) reported that parboiled white and brown rice obtained a cooking time of 56 and 52 minutes respectively.

Water uptake is a measure of the hydration characteristics of rice, which may be influenced by factors such as gelatinization temperature and porosity of kernels (Bandyopadhyay and Roy, 1992). The maximum water uptake was recorded in *Ezhome-4* (8.71 ml) rice variety in raw samples and the minimum was recorded in *Samyuktha* (7.39 ml) in both raw and parboiled rice. Ali and Ojha (1976) reported that total water uptake on cooking is generally more in old rice than fresh samples. It has been reported that rice varieties with high amylose content absorb more water and have a fluffy texture after cooking (Frei and Becker, 2003). In line with this, lowest amylose content was observed in *Samyuktha* rice variety which absorbed minimum amount of water and obtained a lower mean score for texture after cooking. According to Otegbayo *et al.* (2014) water uptake of 10.21 and 10.31ml was observed in brown and white raw rice.

An increase in water uptake was observed in all parboiled rice varieties. According to Neelofer (1992) parboiling changes the absorptive capacity of rice and radically alters the hydration characteristics. Thus, parboiled rice samples were found to absorb a higher amount of water while cooking. Higher water

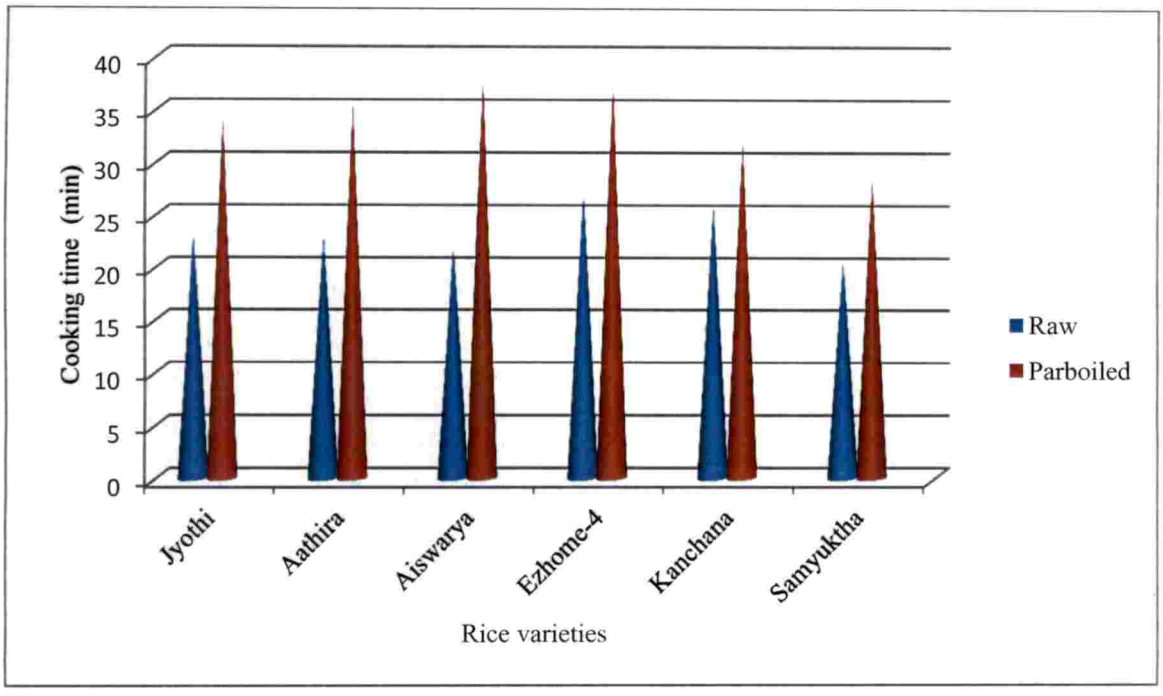


Fig. 9. Cooking time of raw and parboiled rice varieties

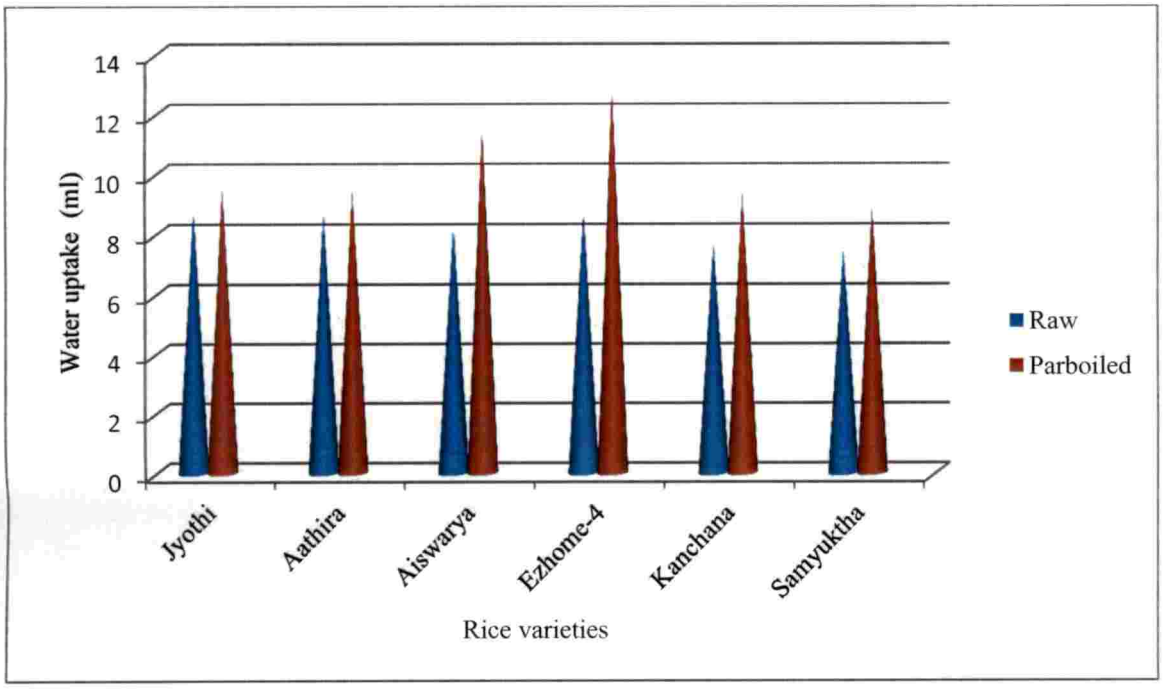


Fig. 10. Water uptake of raw and parboiled rice varieties

uptake is an indicator of better cooking quality of rice (Kandathil, 1997). Ibukun (2008) reported that parboiling of paddy resulted in increased water uptake. According to Otegbayo *et al.* (2014), parboiled white and brown rice observed a water uptake of 13.56 and 10.62 ml respectively. The author also reported that parboiled rice has higher water uptake which may be due to the steaming pressure during parboiling which in turn affects starch gelatinization.

Volume expansion is very important in determining the quality of cooked rice grains. Higher volume expansion ratio after cooking is a desirable trait preferred by consumers. In raw samples, the highest volume expansion ratio was recorded in *Ezhome-4* (5.43) variety and the lowest was recorded in *Samyuktha* (4.35) variety. Nandini (1995) and Sathyan (2012) observed a volume expansion of 5.45 and 4.10 in *Jyothi* variety respectively. Chandhni (2015) reported a volume expansion of 6.07, 4.49, 5.18 and 5.60 in Uma, Prathyasha, Ezhome-1 and Ezhome-2 respectively.

In parboiled samples, the volume expansion was in the range of 4.77 (*Samyuktha*) to 5.70 (*Jyothi*). The process of parboiling involves operations like soaking and steaming which results in the higher volume expansion in parboiled samples. Volume expansion ratio of 4.82 to 6.50 was noticed in parboiled rice by Kandathil (1997). Nandini (1995) observed a volume expansion ratio 5.40 in parboiled *Jyothi* variety.

Amylose and amylopectin are the major starch portions in rice. Amylose is a long straight starch molecule and rice with more amylose content tends to cook fluffy with separate grains (Jains *et al.*, 2012). In raw samples, the highest amylose content of 24.90 per cent was observed in *Aathira* and the lowest of 23.23 per cent was observed in *Samyuktha* rice variety. Government of India (2013) reported that Kaipad rice varieties Ezhome-1, Ezhome-2, Kuthiru and Orkayama obtained an amylose content of 26.40 per cent, 29 per cent, 24.99 per cent and 23.64 per cent respectively, which was close to the amylose content of

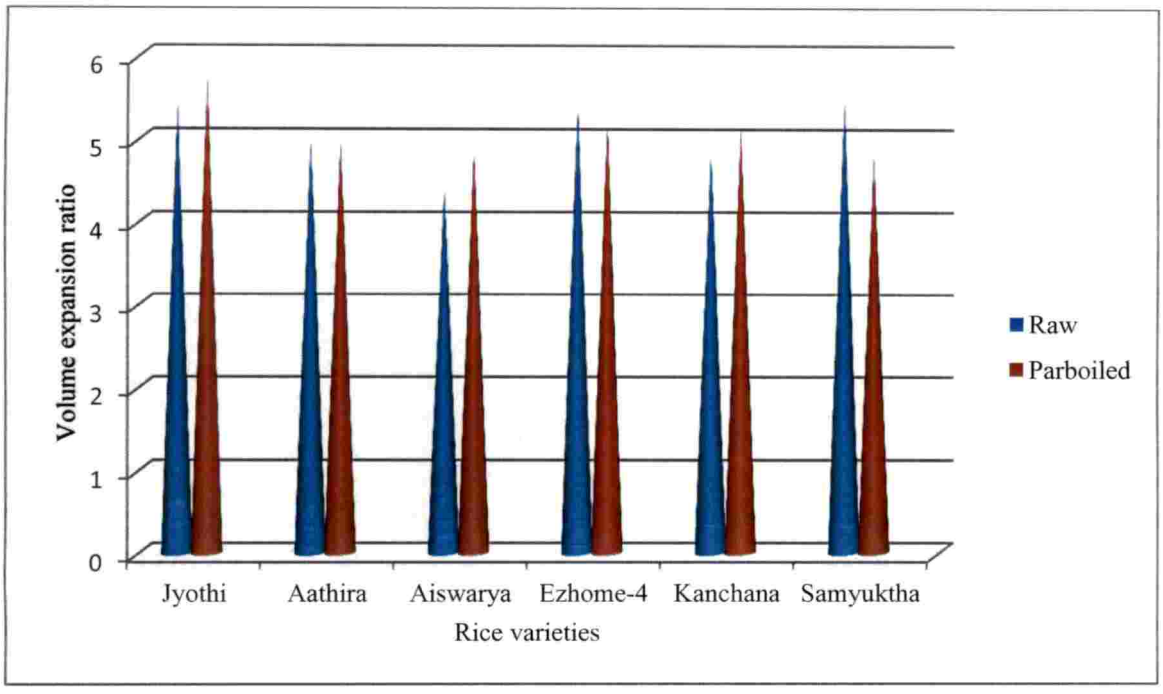


Fig. 11. Volume expansion ratio of raw and parboiled rice varieties

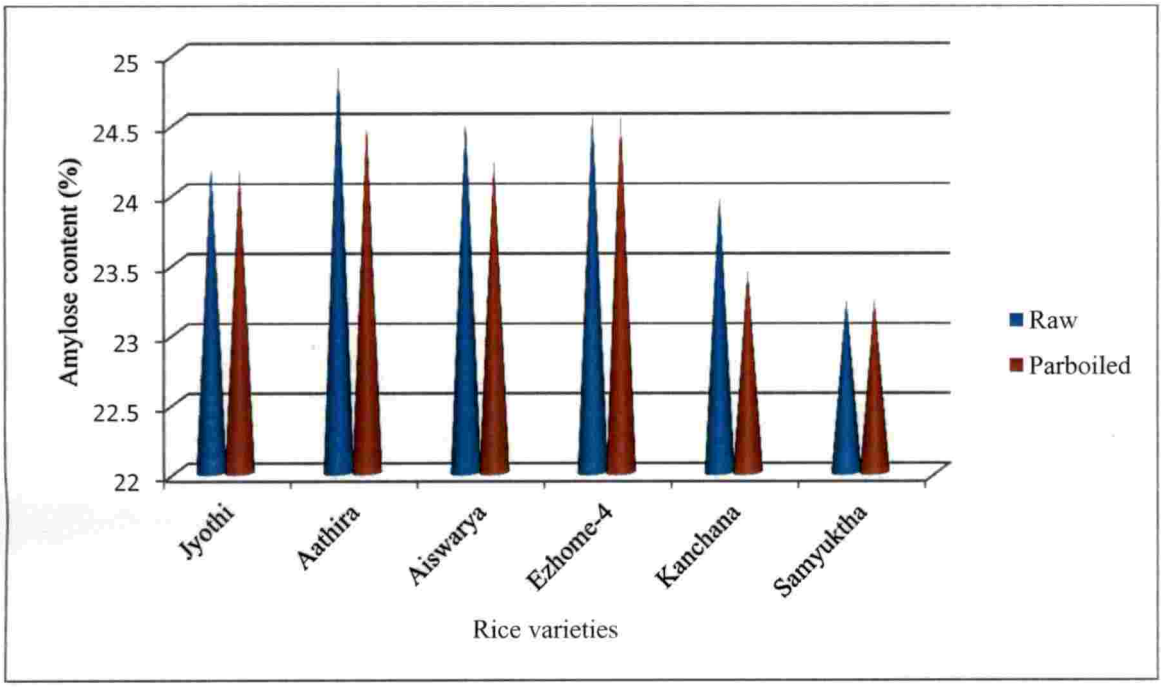


Fig. 12. Amylose content of raw and parboiled rice varieties

Ezhome-4 (24.58). According to Yadav *et al.* (2007) amylose content of Indian rice cultivars ranged from 22.5 per cent to 22.21 per cent.

Otegbayo *et al.* (2014) reported that white raw rice contains 28.58 per cent of amylose content and brown raw rice contains 22.39 per cent of amylose. According to Saika *et al.* (2012) amylose content of pigmented and non-pigmented rice varieties was 22.2 and 28.8 respectively. Amylose content of aromatic rice ranged from 14.23 per cent to 23.01 per cent (Asaduzzamam *et al.*, 2013).

In parboiled samples, a decreased amylose content was observed in the range of 23.03 per cent (*Samyuktha*) to 24.54 per cent (*Ezhome-4*). According to Gariboldi (1974) amylose content is less in parboiled samples than non- parboiled samples because of the starch solubilisation and leaching of the amylose molecules into the surrounding water during soaking and subsequent steaming during parboiling. Lakshmi (2011) observed an amylose content of 22.53 per cent in parboiled *Jyothi* variety.

The gel length in raw samples ranged from 62.21mm (*Samyuktha*) to 55.76mm (*Ezhome-4*). Gel consistency is related to the eating quality of rice as higher the gel the harder the rice is (Kanlayakrit and Maweang, 2013). Similar to this, *Samyuktha* observed a higher gel length which was observed a harder texture after cooking in this study. Chandhni (2015) observed a lower gel length of 29.89mm in Ezhome-1 variety. Sathyan (2012) and Chandhni (2015) observed a gel length of 48.10mm and 37.2mm in *Jyothi* variety respectively. But a higher gel length of 57.30 was observed in the present study. Indian rice cultivars Sharbati and HBC-19 obtained a gel consistency of 54mm and 58mm respectively (Chemutai *et al.*, 2016). The author also reported that the variation in gel consistency may be due to the genetic background of the rice genotypes.

In the present study, gel length of parboiled samples ranged from 24.66mm (*Jyothi*) to 51.33mm (*Aiswarya*). A decrease in gel consistency was observed after parboiling due to the decrease in starch content on parboiling

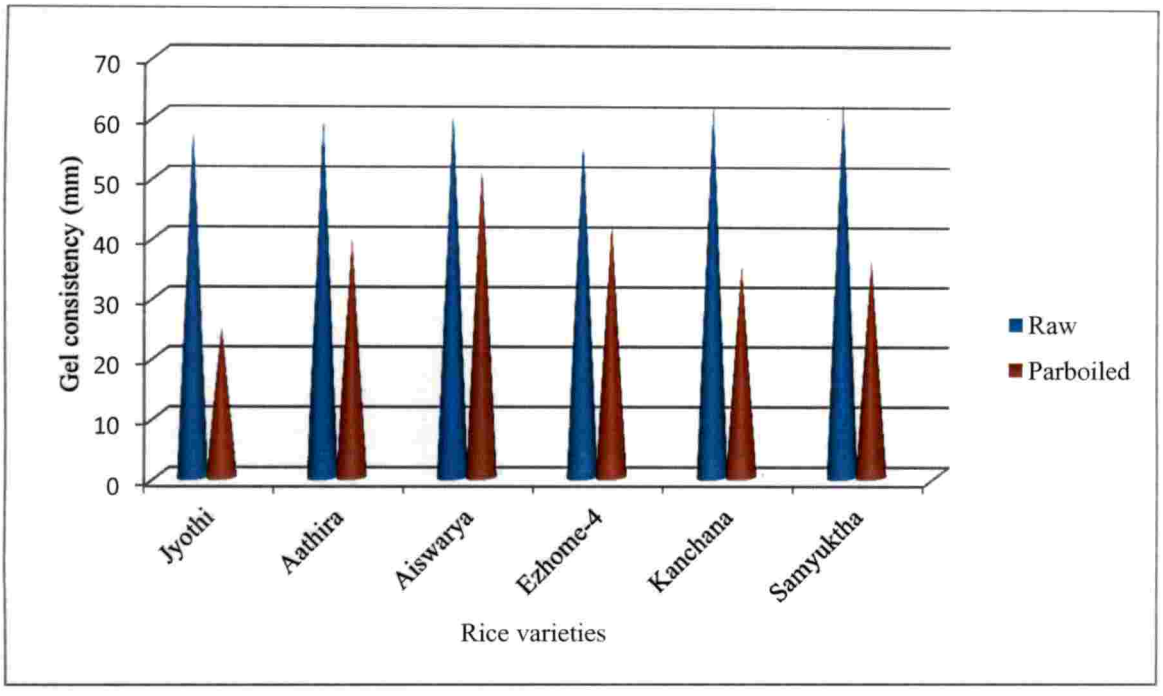


Fig. 13. Gel consistency of raw and parboiled rice varieties

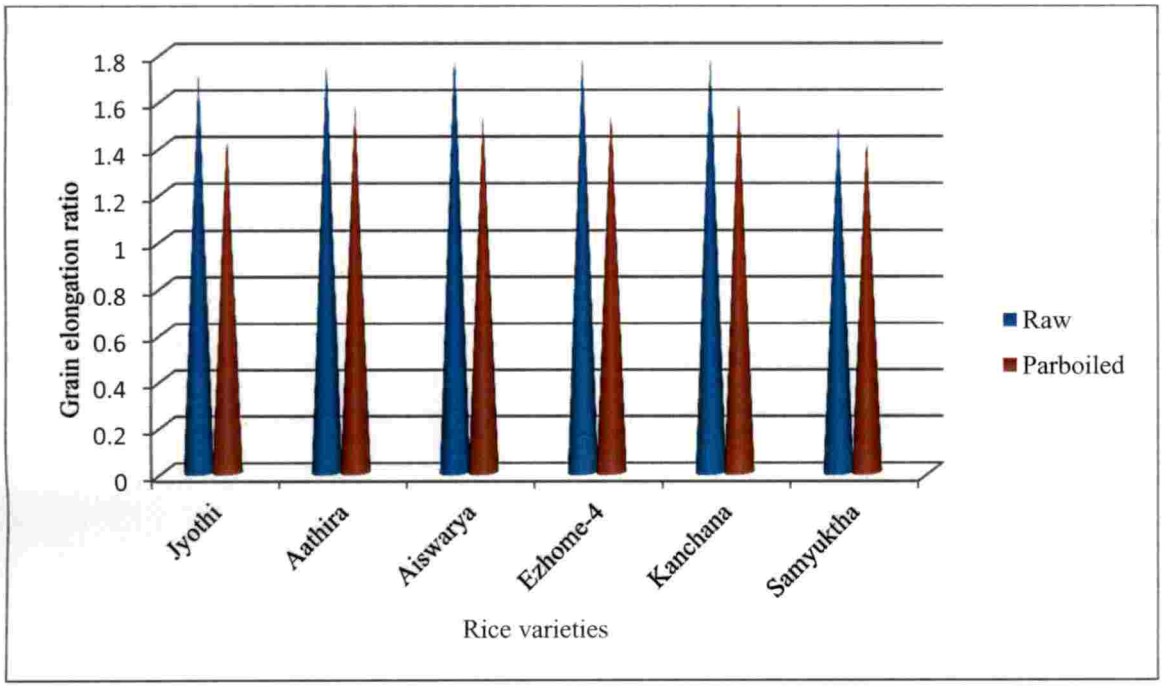


Fig. 14. Grain elongation ratio of raw and parboiled rice varieties

which in turn resulted in less gelatinistion (Ayernor and Ocloo, 2007). A higher gel length of 43.33mm was observed in parboiled *Jyothi* variety (Lakshmi, 2011). According to Biswas and Juliano (1988) gel consistency of parboiled rice ranged from 26mm to 58mm in Indian rice varieties.

The elongation of rice grains after cooking was found to be an important quality parameter contributing to finer appearance (Dipti *et al.*, 2003). In the present study, grain elongation ratio was in the range of 1.47 (*Samyuktha*) to 1.79 (*Aiswarya*). Yadav *et al.* (2007) observed elongation ratio in the range of 1.52 to 1.89 in Indian rice cultivars. *Ezhome-4* obtained a grain elongation ratio of 1.78 in the present study. But a lower ratio of 1.40 and 1.50 was observed in Ezhome-1 and Ezhome-2 respectively by Government of India, (2013). Vanaja *et al.* (2003) reported a grain elongation ratio of 1.45 for Ezhome-3 rice variety. Vanaja and Babu (2006) found that the rice varieties such as *Jyothi* and Matta Triveni obtained grain elongation ratio of 1.20 and 1.32 respectively. Sathyan (2012) observed a grain elongation ratio of 1.80 in raw *Jyothi* variety.

The grain elongation ratio in the parboiled samples ranged from 1.43 (*Samyuktha*) to 1.61 (*Kanchana*). *Jyothi* observed elongation ratio of 1.44 in the present study. In line with this, Lakshmi (2011) observed an elongation ratio of 1.43 in parboiled *Jyothi* variety. According Sareepuang *et al.* (2011) grain elongation ratio was decreased from 1.19 to 1.08 after parboiling. This may be due to the stronger structure of rice starch as a result of gelatinization process. The author also reported that parboiled Super Basmati obtained an elongation ratio of 1.75.

5.1.4. Nutritional qualities of raw rice and parboiled rice

Moisture content is one of the most important factors influencing the quality and overall economic value of rice. In the present study, moisture content in raw rice varied from 10.5 to 12.5 per cent. The highest moisture content (12.5) was observed in *Aiswarya* rice variety. Sathyan (2012) and Chandhni (2015) observed moisture content of 12.67, 10 in *Jyothi* variety respectively. According

to Chandhni (2015) moisture content of 8.5, 10.3, 10.4, 10.6 and 11.6 was observed in Ezhome-2, Uma, Vyttila-8, Vaishak and Ezhome-1 respectively. A moisture content of 13.3 per cent was observed by Suganthi and Naccbair (2015) in Uma rice variety.

Otegbayo *et al.* (2001) reported a moisture content of 9.70 and 9.60 in white and brown rice respectively. Yadav *et al.* (2007) reported moisture content in the range of 11.64 to 12.72 per cent in Indian rice cultivars. According to Ayernor and Ocloo (2007) moisture content of rice varied from 9.06 to 13.50 per cent in raw rice varieties. Jamila *et al.* (2015) reported that moisture content is an important quality index of grains and that moisture content ranging from 9 to 11 per cent is safe for storing milled grains.

Much variation in moisture content of raw and parboiled varieties were observed in the present study. Moisture content of parboiled varieties ranged from 9.70 (*Jyothi*) to 11.56 (*Aiswarya*) in the present study. Otegbayo *et al.* (2001) observed a moisture content of 10.30 and 9.50 in parboiled white and brown rice. According to Ibukun (2008) parboiled rice contains 13.6 per cent of moisture. Chukwu and Oseh (2009) reported that raw rice contains 17 per cent of moisture and which was decreased by 12 per cent after parboiling. Lakshmi (2011) reported that parboiled *Jyothi* variety contains 12.10 per cent of moisture. According to Anuonye *et al.* (2016) moisture content in parboiled varieties ranged from 8.24 to 10.21 per cent.

Starch content of different rice varieties were found to be in the range of 65.83g/100g (*Jyothi*) to 70.50g/100g (*Aiswarya*) in the present study. Chandhni (2015) observed a lower starch content of 63.18g/100g but Sathyan (2012) observed a higher starch content of 79.61g/100g in *Jyothi* variety. Sugeetha (2010) reported that KAU variety MO8-20-KR contains 76.25g/100g of starch content. Omar *et al.* (2016) reported that starch content of rice samples was found to be in the range of 81.23 to 92.73g/100g. According to Chandhni (2015) starch content of 72g/100g, 34.38g/100g, 38.79 g/100g, 51.57g/100g, 57.1g/100g and

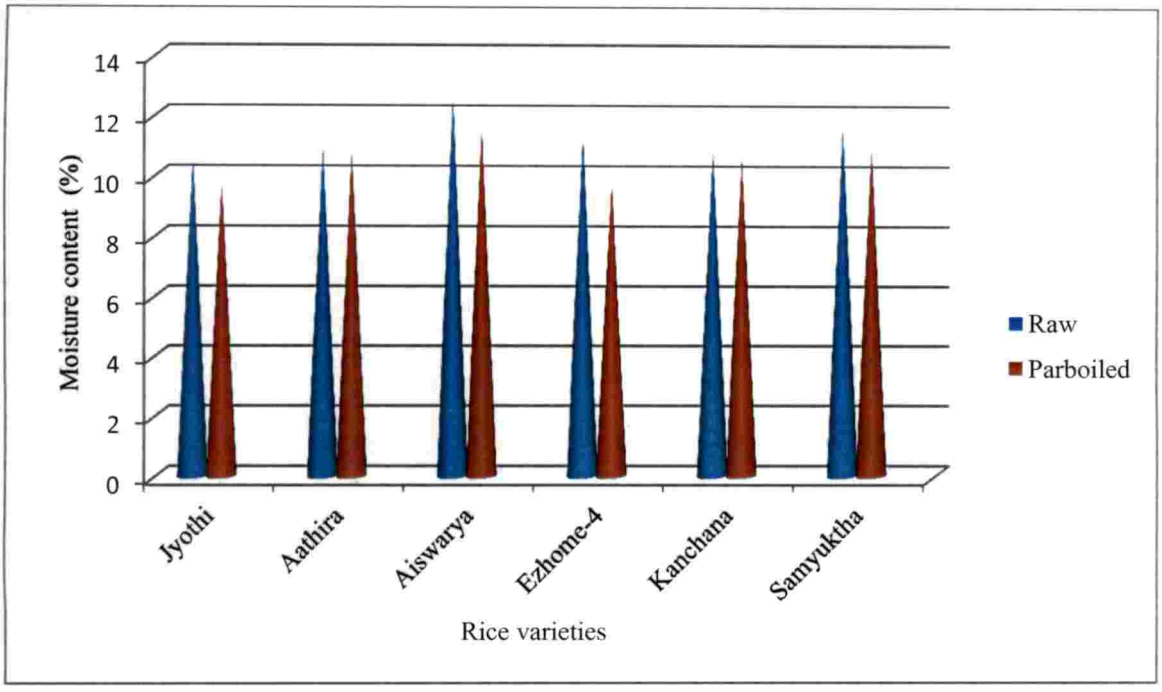


Fig. 15. Moisture content of raw and parboiled rice varieties

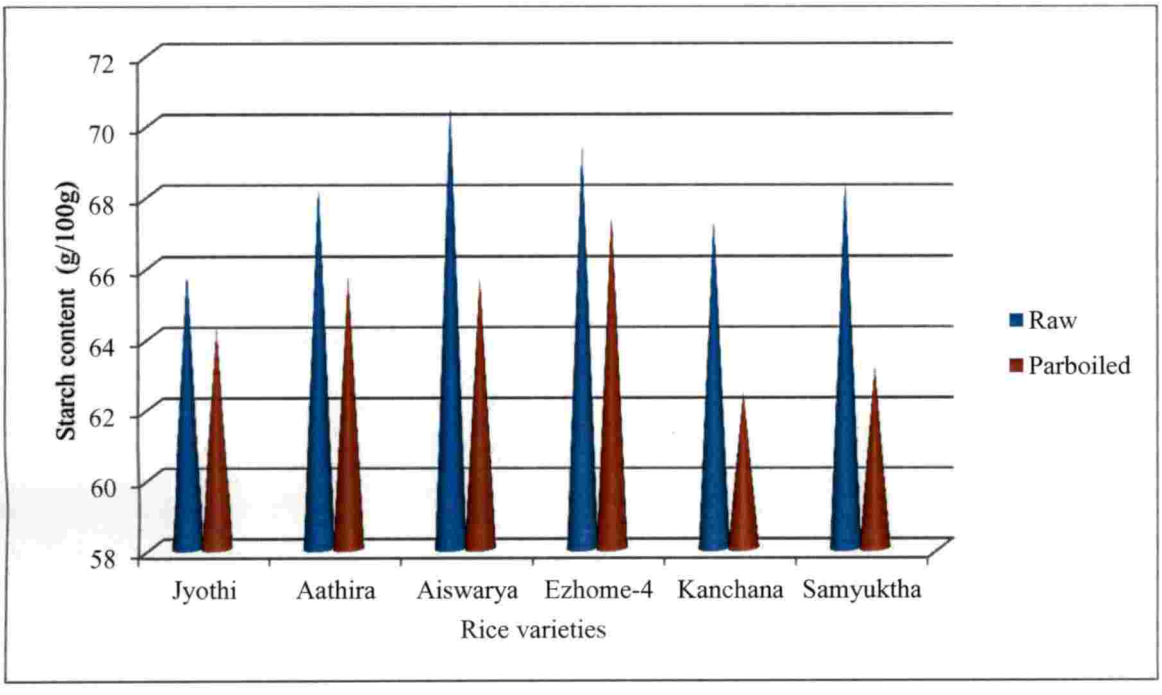


Figure 16. Starch content of raw and parboiled rice varieties

55.2g/100g in Ezhome-2, Prathyasha, Vyttila-8, Vaishak, Ezhome-1 and Uma respectively.

In the present study, a slight decrease in starch content was observed in parboiled rice varieties. The starch content ranged from 62.40g/100g (*Kanchana*) to 67.43g/100g (*Ezhome-4*). According to Kale *et al.* (2017) starch content in raw rice was found to be 73.24g/100g and which decreased to70.50g/100 after parboiling. This decrease in starch content might be due to leaching of amylose during heating in water and also due to the formation of amylose-lipid complexes during hydrothermal process.

Rice protein is valuable because it ranks rich in essential amino acid lysine and high in nutritional quality among the cereal proteins (Bean and Nishita, 2000). In the present study, the highest protein content was observed in *Ezhome-4* (5.50g/100g) and the lowest was in *Samyuktha* (4.70g/100g). According to Yadav *et al.* (2007) protein content of Indian rice cultivars ranged from 5.46 to 7.02g/100mg. Deepti *et al.* (2008) observed a protein content of 7.97g/100g in raw *Jyothi* variety. Protein content of 6.8g/100g and 5.58g/100g was observed by Gopalan *et al.* (2012) and Marie *et al.* (2016) in raw rice varieties.

A slight decrease in protein content was observed after parboiling in the present study. According to Chukwu and Oseh (2009) soaking cause protein bodies to sink into the compact mass of gelatinized starch making it less extractable. Decrease in protein content might be due to leaching of protein during soaking phase of parboiling as well as rupturing that occurs in molecules during steaming phase (Akther *et al.*, 2015). In the present study, protein content of 3.12g/100g was observed in *Jyothi* variety but Lakshmi (2011) observed a higher protein content of 7.55g/100g in parboiled *Jyothi* variety.

The fat content in rice consists essentially of unsaturated fatty acids and has great influence on appearance and eating quality of rice. In the present study, the fat content ranged from 0.31g/100g (*Samyuktha*) to 0.48g/100g (*Aathira*) in raw samples. Yadav *et al.* (2007) observed a fat content in the range of 0.54 to

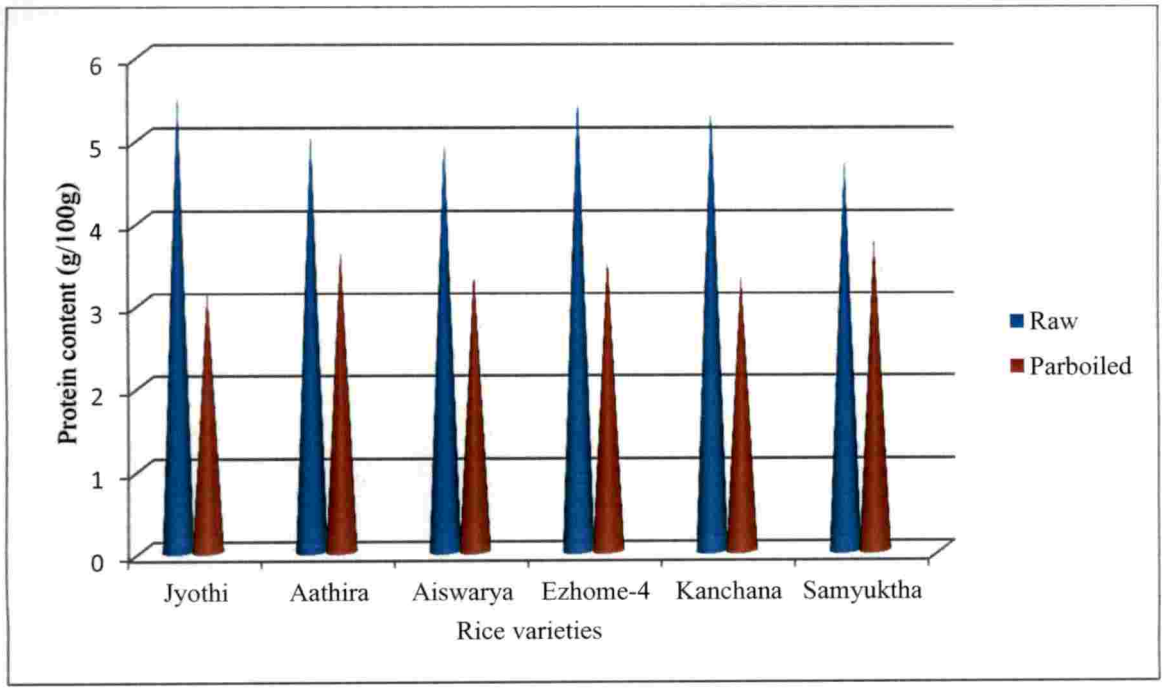


Figure 17. Protein content of raw and parboiled rice varieties

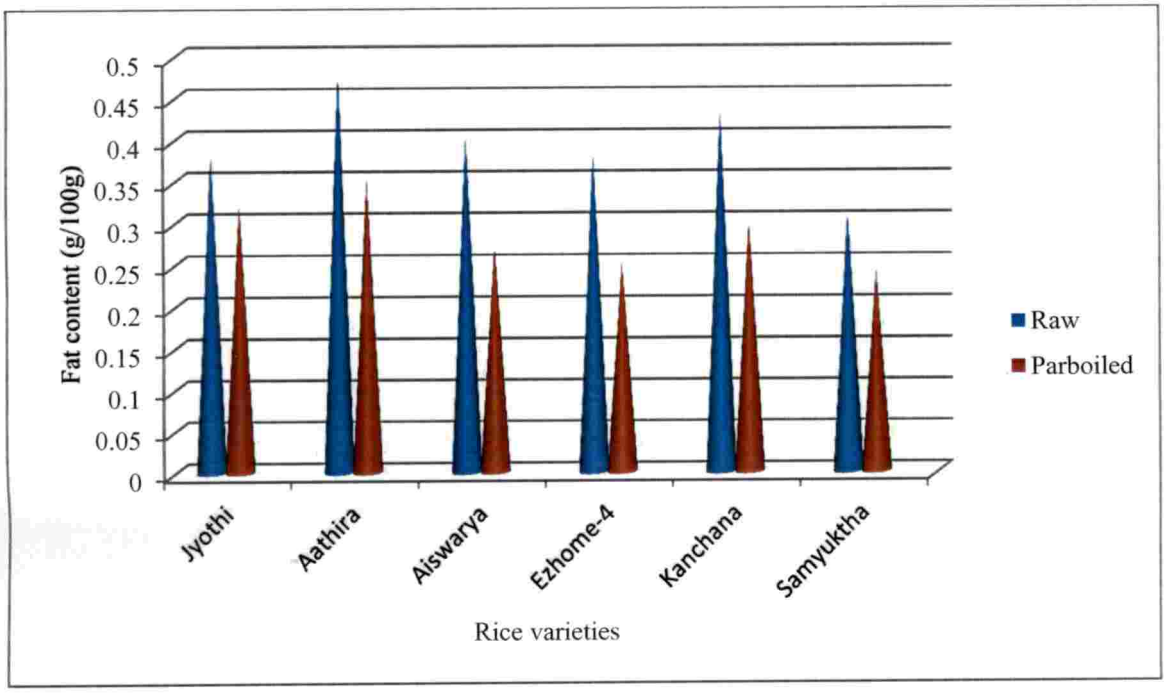


Figure 18. Fat content of raw and parboiled rice varieties

0.82g/100g in Indian rice cultivars. Sathyan (2012) observed fat content of 1.92g/100g in raw *Jyothi* variety. Thomas *et al.* (2013) reported that brown rice contains 1.74g/100g protein. According to Chandhni (2015) fat content of 0.3g/100g, 0.35g/100g, 0.42g/100g, 0.53g/100g, 0.64g/100g and 0.71g/100g in Ezhome-2, Uma, *Jyothi*, Prathyasha, Ezhome-1 and Vaishak respectively.

In the present study, fat content in parboiled rice varieties ranged from 0.25g/100g (*Ezhome-4*) to 0.35g/100g (*Aathira*). Parboiled rice variety contains 0.8g/100g of fat (Ibukun, 2008). According to Sareepuang *et al.* (2008) parboiled brown rice contains 1.99g/100g. Lakshmi (2011) observed a fat content of 1.30g/100g of fat in parboiled *Jyothi* variety. According to Roy *et al.* (2011) parboiled Basmati rice contains 0.3g/100g of lipids.

Rice is reported to be a moderate source of fibre. In the present study the highest fibre content of 0.31g/100g was observed in *Samyuktha* and *Ezhome-4* and the lowest of 0.18g/100g was observed in *Jyothi* variety. Nandini (1995) observed the highest fibre content of 0.51g/100g in traditional rice variety Kutticheradi. Gopalan *et al.* (2007) observed a fibre content of 0.2g/100g in parboiled rice variety. A fibre content of 1.07g/100g was observed by Sathyan (2012) in raw *Jyothi* rice variety.

In the present study, an increase in fibre content in parboiled rice varieties was observed which ranged from 0.23g/100g (*Jyothi*) to 0.34g/100g (*Kanchana*). According to Ibukun (2008) parboiled rice contains 1.28g/100g of dietary fibre. Lakshmi (2011) observed a fibre content of 0.83g/100g in parboiled *Jyothi* variety.

Brown rice is a rich source of B vitamins. In the present study, the highest thiamine content of 0.080mg/100 was observed in *Aiswarya* and the lowest of 0.060mg/100g was observed in *Samyuktha* rice variety. Chandhni (2015) observed a thiamine content of 0.06mg/100g in both Ezhome-1 and Ezhome-2 variety but a slightly higher amount of 0.063mg/100g of thiamine was observed in *Ezhome-4* in the present study. Deepa *et al.* (2008) reported that raw rice contains

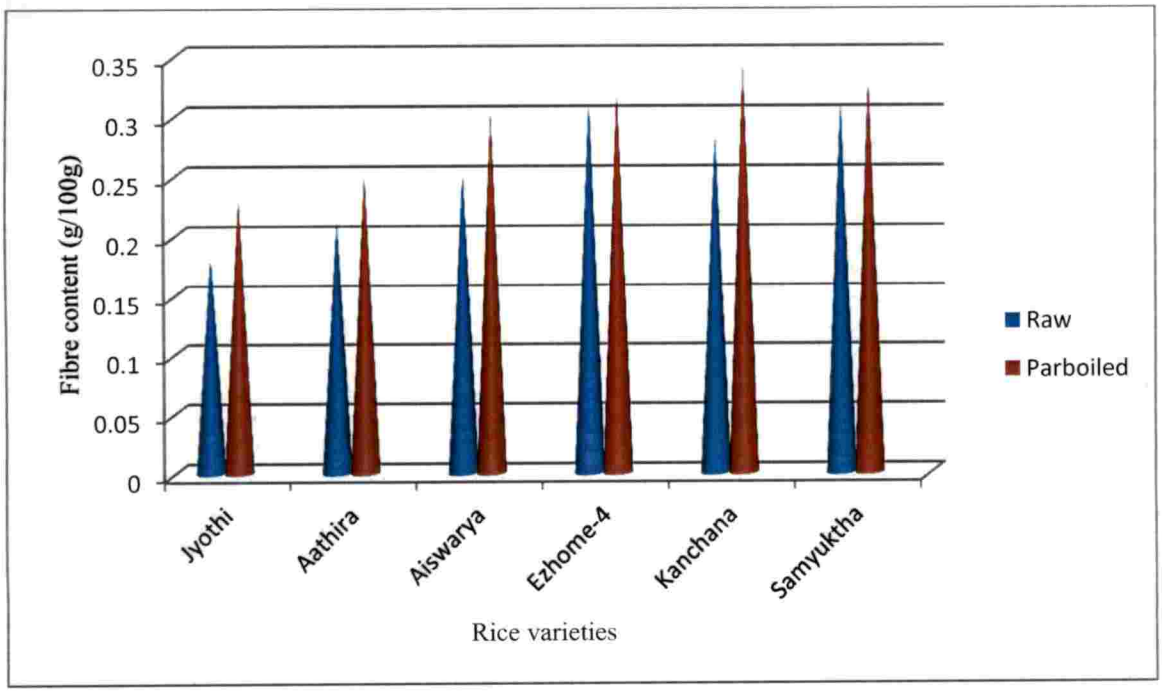


Fig. 19. Fibre content of raw and parboiled rice varieties

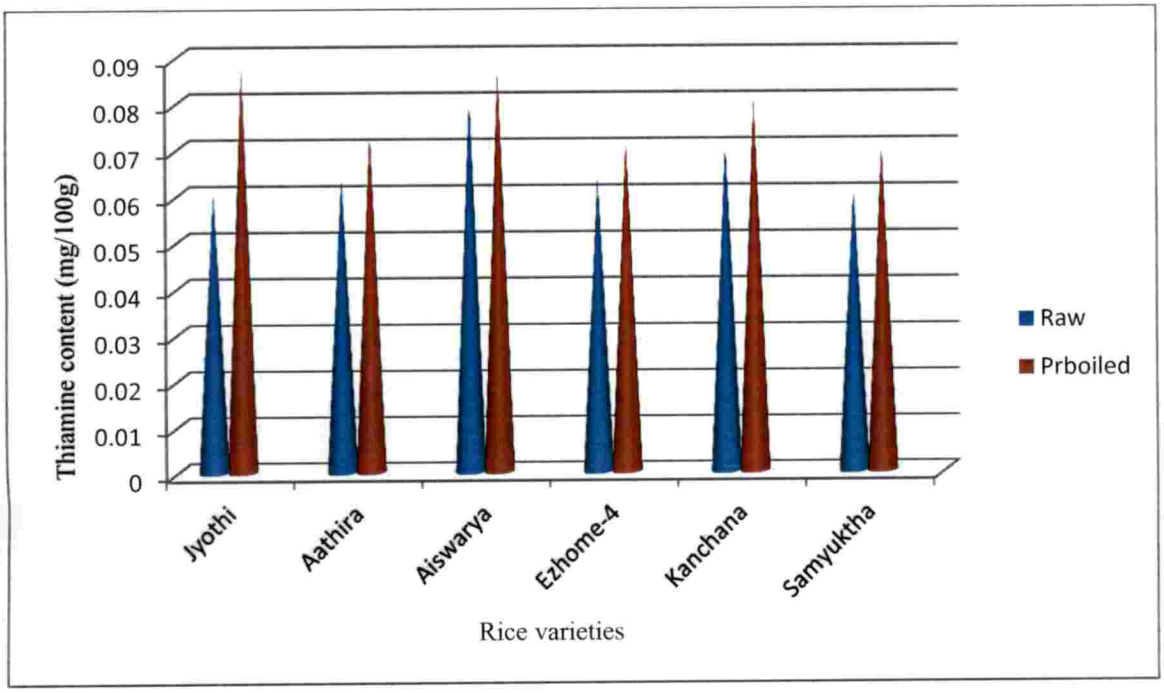


Fig. 20. Thiamine content of raw and parboiled rice varieties

0.35mg/100g of thiamine. Sugeetha (2010) observed a thiamine content of 0.29mg/100g in MO-95-1 variety. Sathyan (2012) observed a thiamine content of 0.05mg/100 in raw *Jyothi* variety. According to Chandhni (2015) Vaishak and Vyttila-8 variety contains 0.07mg/100g and 0.02mg/100g of thiamine respectively.

A slight increase in thiamine content was observed in the present study after parboiling. When rice is steamed in the process of parboiling the thiamine contained in the germ and pericarp diffuse through the endosperm (Aykroyd, 2000). Lakshmi (2011) observed a thiamine content of 0.24mg/100g in parboiled *Jyothi* variety. Akther *et al.* (2015) reported that raw rice contains 0.07mg/100g of thiamine and it was increased to 1.02mg/100g after parboiling. Sene *et al.* (2017) reported that a marked increase in thiamine, riboflavin and nicotinic acid in parboiled rice.

Minerals like calcicum, phosphorus, zinc and traces of iron are present in rice (Yousaf, 1992). In the present study, the highest calcium content was observed in *Kanchana* (5.76mg/100g) rice variety and the lowest in *Aiswarya* (4.90mg/100g) rice variety. Sugeetha (2010) reported that KAU variety MO8-20-KR contains 12mg/100g of calcium. According to Sathyan (2012) raw *Jyothi* variety contains 5.94mg/100g of calcium. Parboiled *Jyothi* variety contains 6.50mg/100g of calcium (Lakshmi, 2011). According to Chandhni (2015) the calcium content is 5mg/100g and 4.92mg/100g in Prathyasha and Ezhome-1 respectively.

In the present study, the highest zinc content as observed in *Aathira* (1.32mg/100g) and the lowest was in *Jyothi* (1.09mg/100g). In line to this, Chandhni (2015) reported that rice varieties Ezhome-2, Vyttila-8, Prathyasha, Ezhome-1 and Vaishak contains zinc content of 1.31, 1.28, 1.17, 1.08 and 1.01 mg/100g respectively.

The highest iron content in present study was observed in *Jyothi* (0.61mg/100) rice variety and the lowest was in *Kanchana* (0.39mg/100g). In line

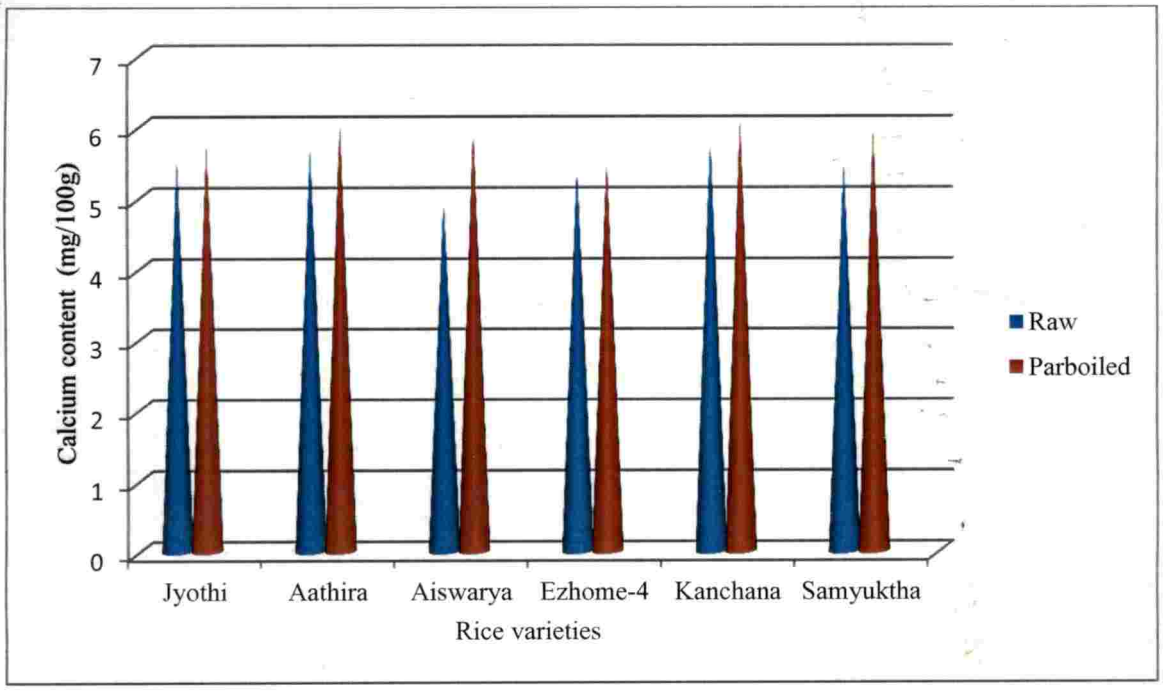


Fig. 21. Calcium content of raw and parboiled rice varieties

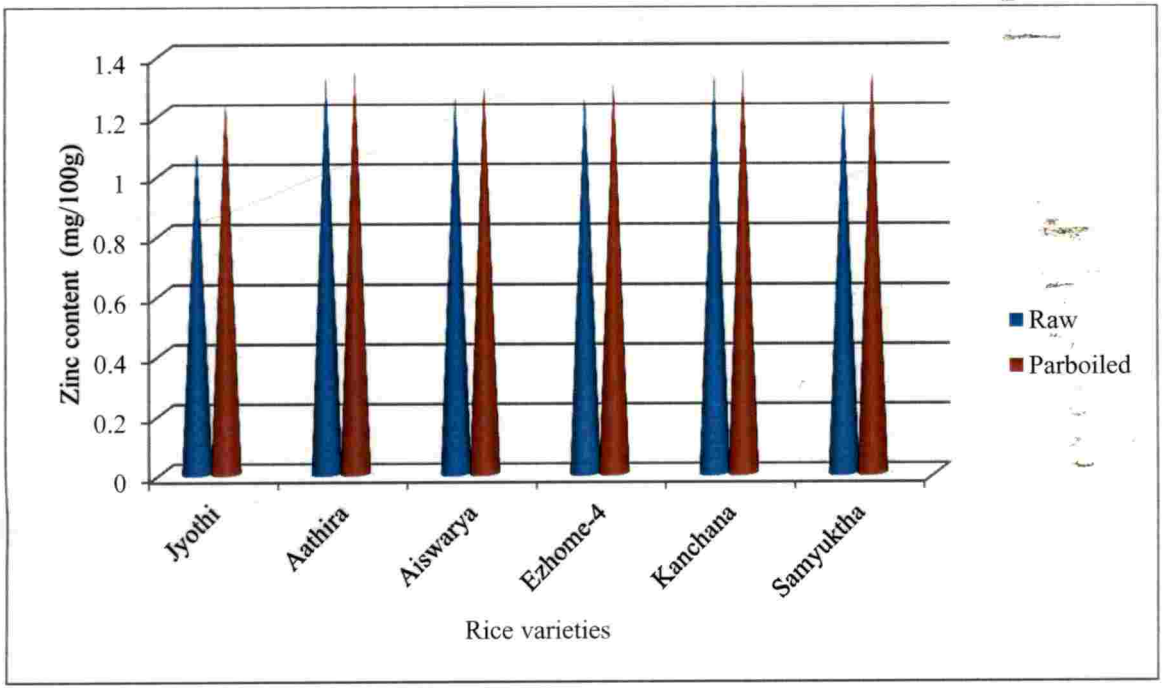


Fig. 22. Zinc content of raw and parboiled rice varieties

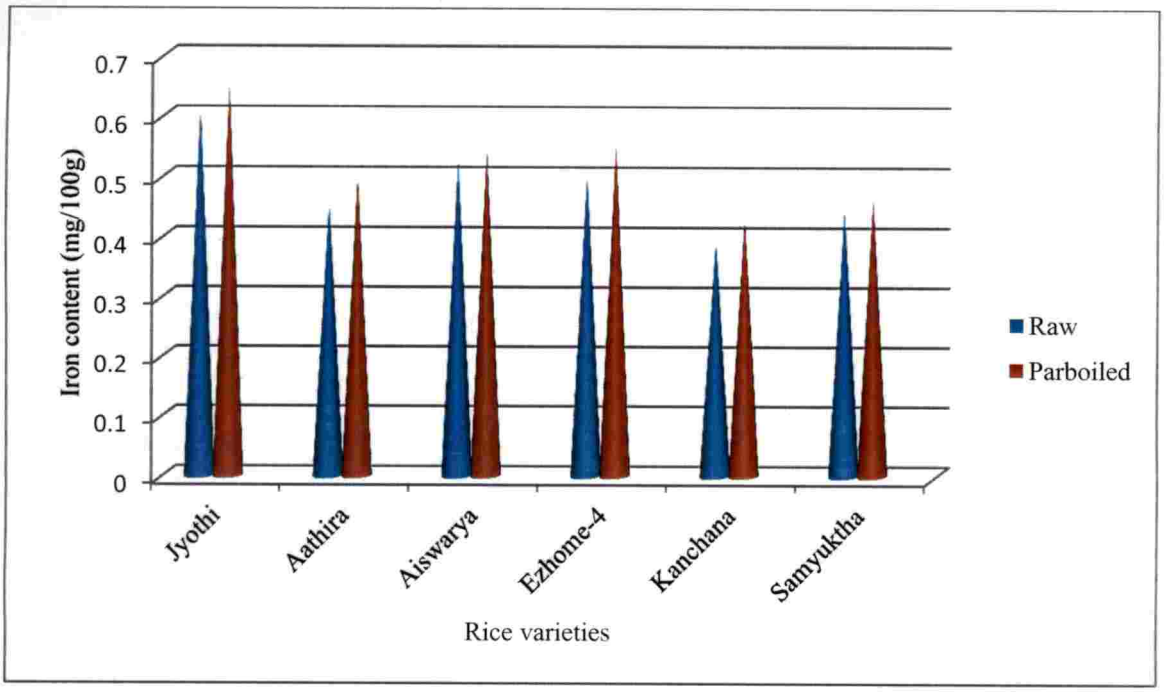


Fig. 23. Iron content of raw and parboiled rice varieties

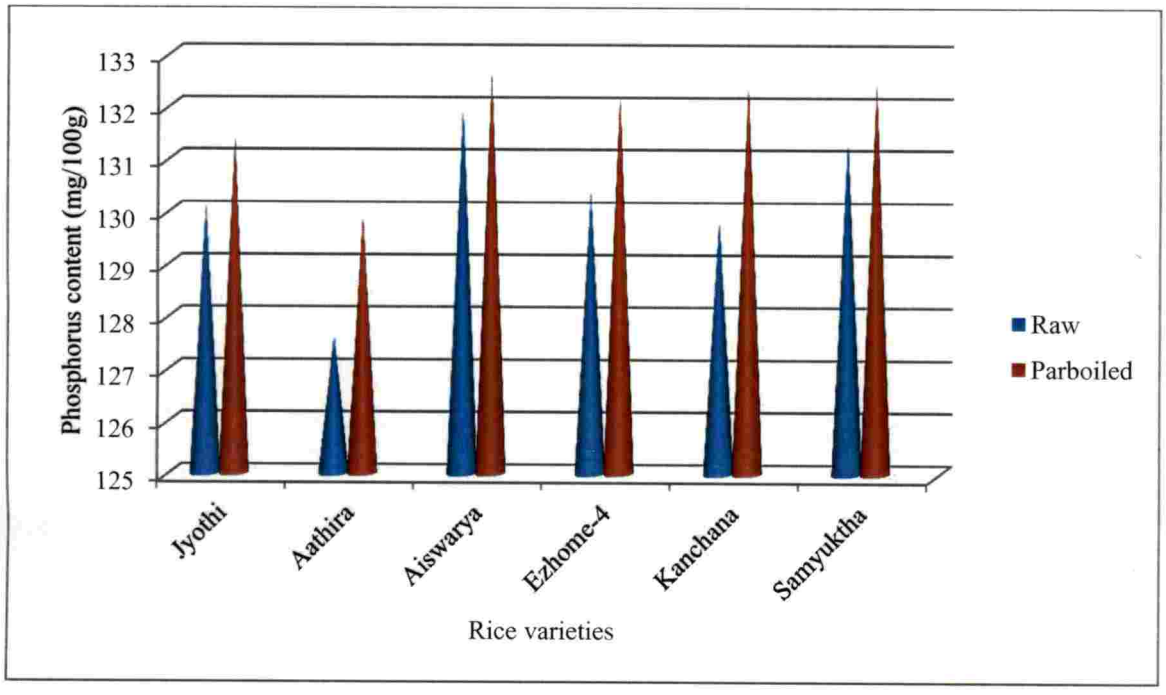


Fig. 24. Phosphorus content of raw and parboiled rice varieties

to this, Chandhni (2015) observed an iron content of 0.61, 0.41, 0.44, 0.47 and 0.51mg/100g of iron in Prathyasha, Ezhome-1, Vyttila-8, Vaishak and Ezhome-2 respectively. According to Lakshmi (2011) parboiled *Jyothi* variety contains 1.97mg/100g of iron. Sathyan observed an iron content of 1.94mg/100g in raw *Jyothi* variety. But Deepa *et al.* (2008) observed a higher iron content of 3.95mg/100g in raw *Jyothi* variety.

In the present study, the highest phosphorus content was observed in *Aiswarya* (131.96mg/100g) and the lowest was in *Aathira* (127.60mg/100g) rice variety. According to Chandhni (2015) varieties Ezhome-2, Vyttila-8, Prathyasha, Ezhome-1 and Vaishak contains a phosphorus content of 135.41, 95.87, 122.87, 128.17 and 90.29mg/100g respectively. A higher phosphorus content of 324mg/100g was observed in raw *Jyothi* variety by Deepa *et al.* (2008). According to Lakshmi (2011) parboiled *Jyothi* variety contains 161.83mg/100g of phosphorus.

The mineral content in parboiled samples are higher than raw samples in the present study. This is might be due to the migration of bran components into the endosperm during hydrothermal treatment (Bhattacharya, 2004).

Starch digestibility varies among different starchy foods, including rice starch, rice flour and cooked rice. In the present study, the highest starch digestibility was observed in *Aathira* (79.06%) and the lowest was in *Ezhome-4* (72.46%). According to Anugrahati *et al.* (2015) raw rice have a digestibility of 77.69 per cent. Frei *et al.* (2003) observed a starch digestibility of 71.8, 74.8, 80.7, 75.7, 80, and 80.9 per cent in six Philippines red rice varieties. The author also reported that significant difference in digestibility among cultivars may be due to the factors such as physicochemical properties, granule size and degree of crystallinity.

Starch digestibility in parboiled samples ranges from 70.06 (*Ezhome-4*) to 76.90 (*Jyothi*) in the present study. Significant decrease was noticed in starch digestibility after parboiling. This is might be due to the tendency of gelatinized

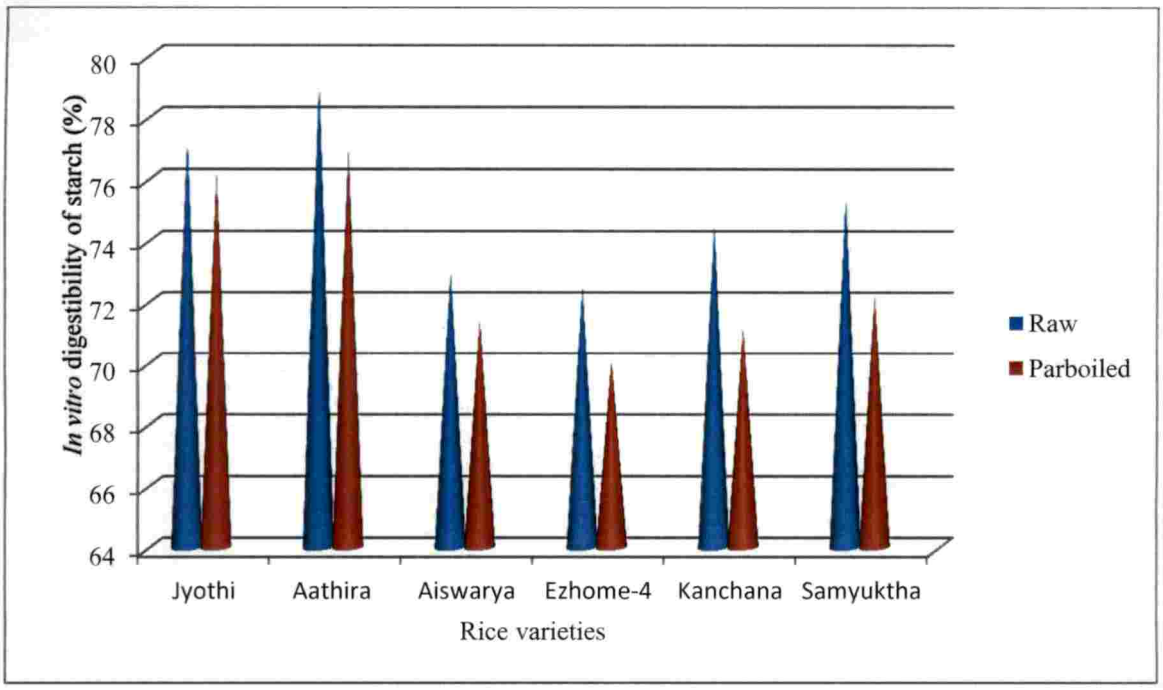


Fig. 25. *In vitro* digestibility of starch content in raw and parboiled rice varieties

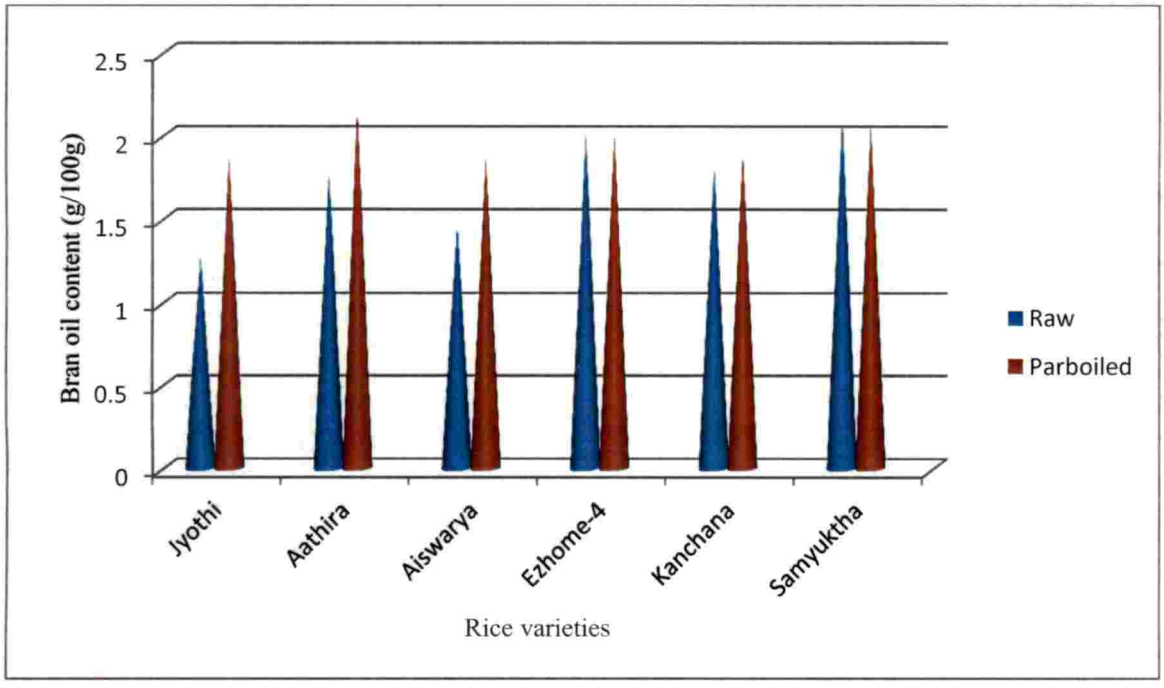


Fig. 26. Bran oil content in raw and parboiled rice varieties

starch during parboiling to undergo retrogradation upon cooling leads to resistant starch formation in parboiled rice grain decreasing the starch digestibility (Mitra *et al.*, 2007). Lakshmi (2011) observed a starch digestibility of 79.20 per cent in parboiled *Jyothi* variety. Odenigbo *et al.* (2013) reported a starch digestibility of 82.4 per cent in non-parboiled samples and 73.9 per cent in parboiled samples.

In the present study, the highest rice bran oil content of 2.10g was observed in *Samyuktha* and the lowest of 1.26g was observed in *Jyothi*. According to Krishna *et al.* (2011) rice bran oil content of 1.78g, 2.06g, 2.54g, 1.85g and 1.74g was observed in Basmati, Punjab Basmati, Anupama, Purva and IR 20 respectively.

5.2.1. Organoleptic evaluation of table rice

Sensory evaluation is a technique to measure the sensory characteristics and acceptance of products being produced. Of all major cereals, rice is the only one that is consumed mostly in the form of cooked whole grains or table rice. In the present study, mean scores for appearance was in the range of 7.51 (*Aiswarya*) to 6.26 (*Ezhome-4*). Nandini *et al.* (2004) reported that, raw rice varieties like Jaya, *Jyothi* and Matta Triveni, showed the highest mean score for appearance. The highest mean score for appearance of table rice was observed in *Aiswarya* rice variety, this may be due to the grain characteristics of *Aiswarya*. The highest grain elongation ratio of 1.78 was also observed in *Aiswarya* variety. *Ezhome-4* variety obtained lowest score for appearance because which is whitish in colour when compared to other varieties. The highest cooking time of 27 minutes was observed in *Ezhome-4* as it is slightly harder which may be the reason for lower acceptability.

According to Singh *et al.* (2000) traditional rice varieties grown in India are of intermediate amylose content and are generally preferred for table rice. In the present study, intermediate amylose content was observed in all varieties except *Samyuktha*.

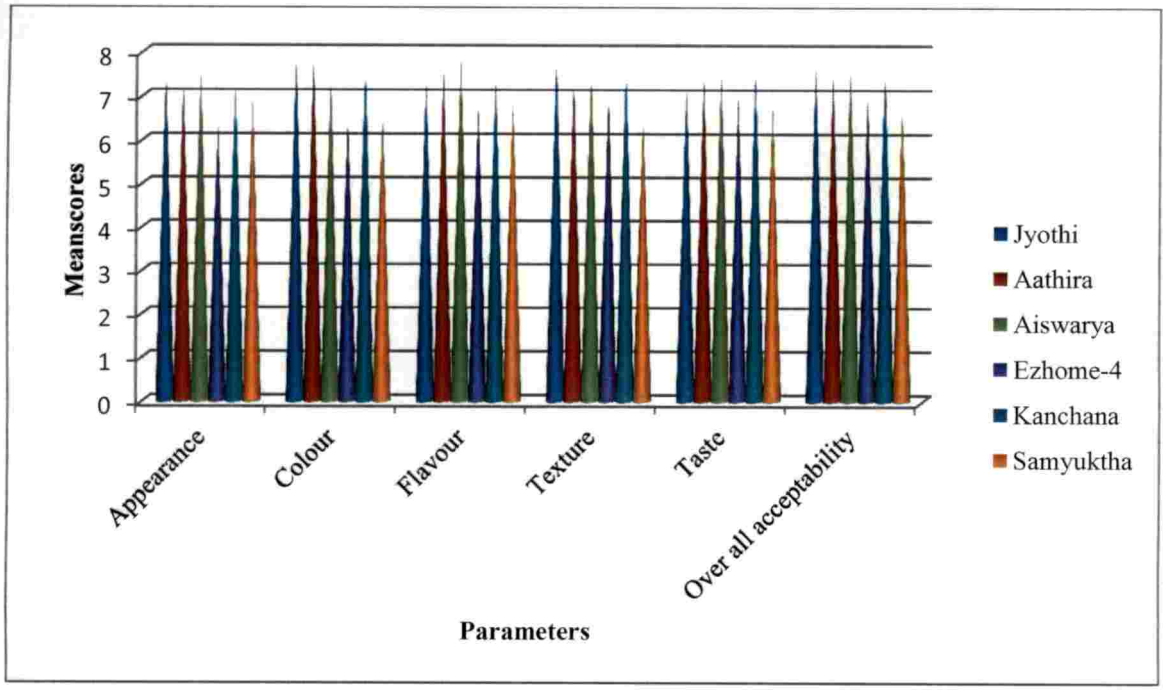


Fig. 27. Mean scores for organoleptic qualities of table rice prepared with raw rice varieties

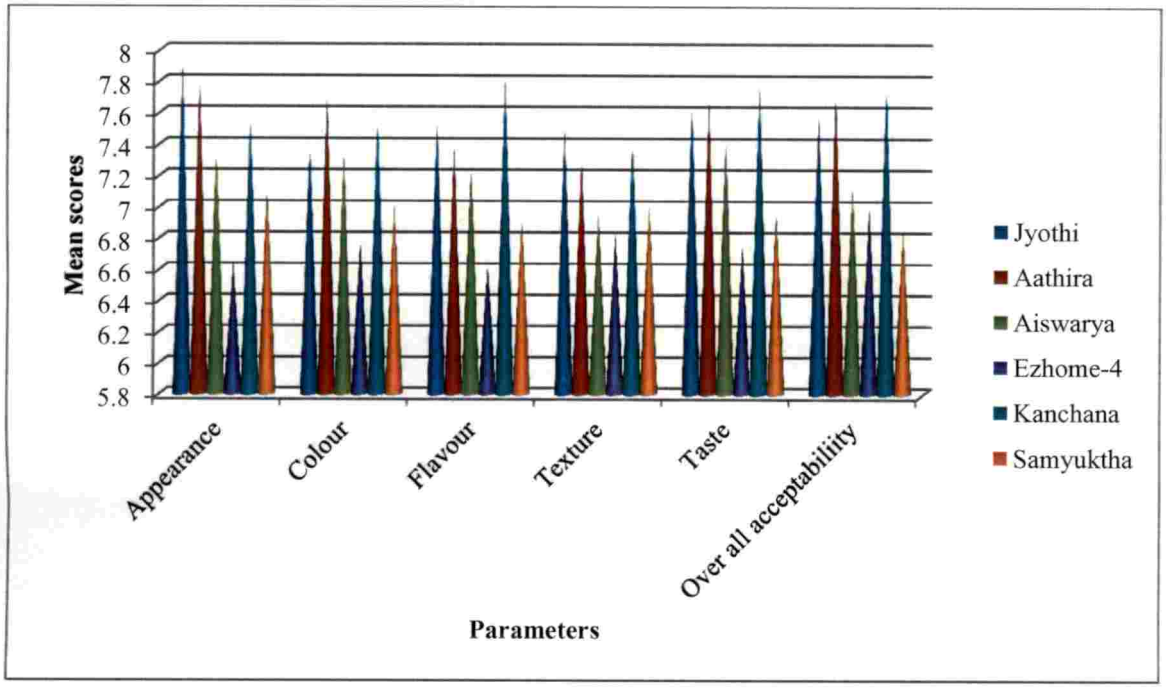


Fig. 28. Mean scores for organoleptic qualities of table rice prepared with parboiled rice varieties

Control variety *Jyothi* obtained higher score for texture (7.82). *Samyuktha* and *Ezhome-4* observed lower grain elongation ratio, this may be the reason for their lower texture after cooking. Rice texture is affected by factors such as variety, amylose content, and gelatinization temperature processing factors and cooking method (Simonelli *et al.*, 2017). The mean scores of taste of cooked rice was in the range of 7.46 (*Aiswarya*) to 6.71 (*Samyuktha*). *Aiswarya* variety obtained higher mean score for almost all attributes in the present study and *Samyuktha* and *Ezhome-4* obtained comparatively lower mean scores for organoleptic qualities.

In parboiled samples, the highest mean score of 7.88 for appearance was observed in control variety *Jyothi*. Cooked rice prepared using parboiled rice obtained a mean score of 7.74 for appearance (Kunhimon, 2010). A slight decrease in mean scores of all quality attributes was observed after parboiling. This is may be due to the hardening of grain after parboiling. Nandhini (1995) reported that *Jyothi* was the most suitable variety for table rice. Divakar and Francies (2010) evaluated the suitability of seven KAU rice varieties, and indicated that the variety Karuna is the most favourable variety for table rice. According to Bello *et al.* (2006) parboiled rice has greater values of hardness, cohesiveness, gumminess, chewiness. The author also reported that parboiled rice was less sticky than raw rice. In the present study, *Ezhome-4* and *Samyuktha* was obtained lower score for all quality attributes both raw and parboiled samples.

Varietal and cultivar differences can be considered as the major factor behind differences in cooking behaviour of rice (Ashogbon and Akintayo, 2012).

5.2.2. Organoleptic evaluation of rice based products

Idli, a popular fermented breakfast food consumed in the Indian subcontinent is made mainly from rice and black gram. It is very popular because of its textural and sensory attributes. In the present study, the highest mean scores of 8.42, 8.04 and 8.04 for texture, taste and over all acceptability was observed in *idli* prepared with *Kanchana* variety. Among raw red rice varieties *Kanchana*

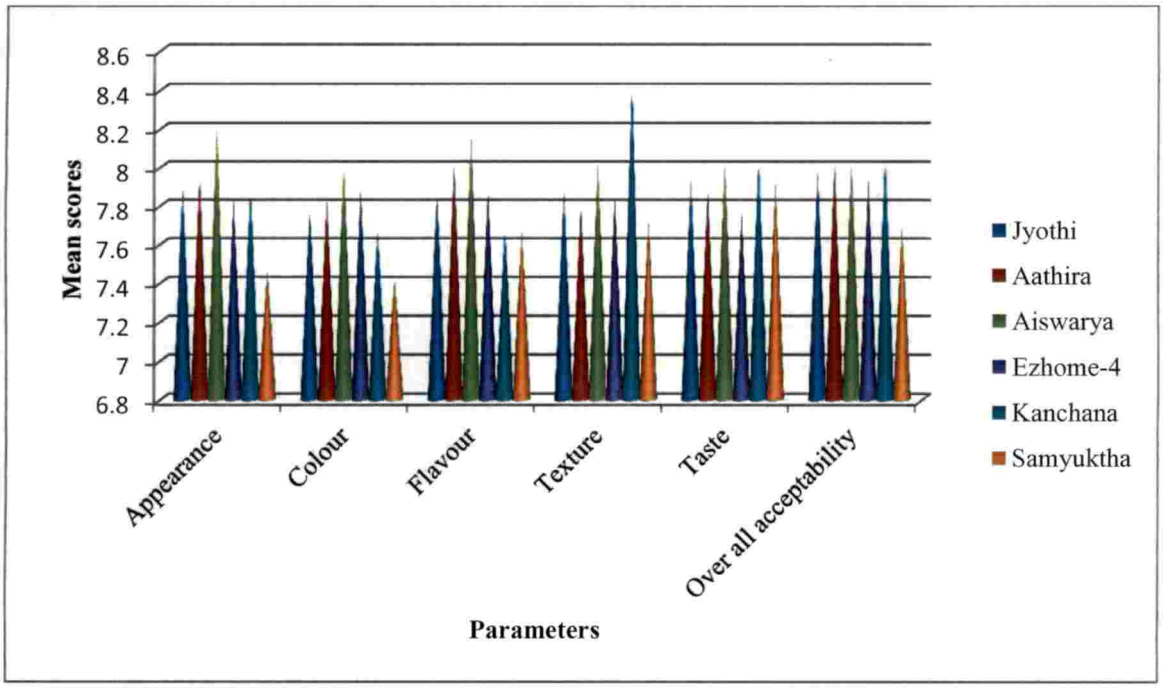


Fig. 29. Mean scores for organoleptic qualities of *idli* prepared with raw rice varieties

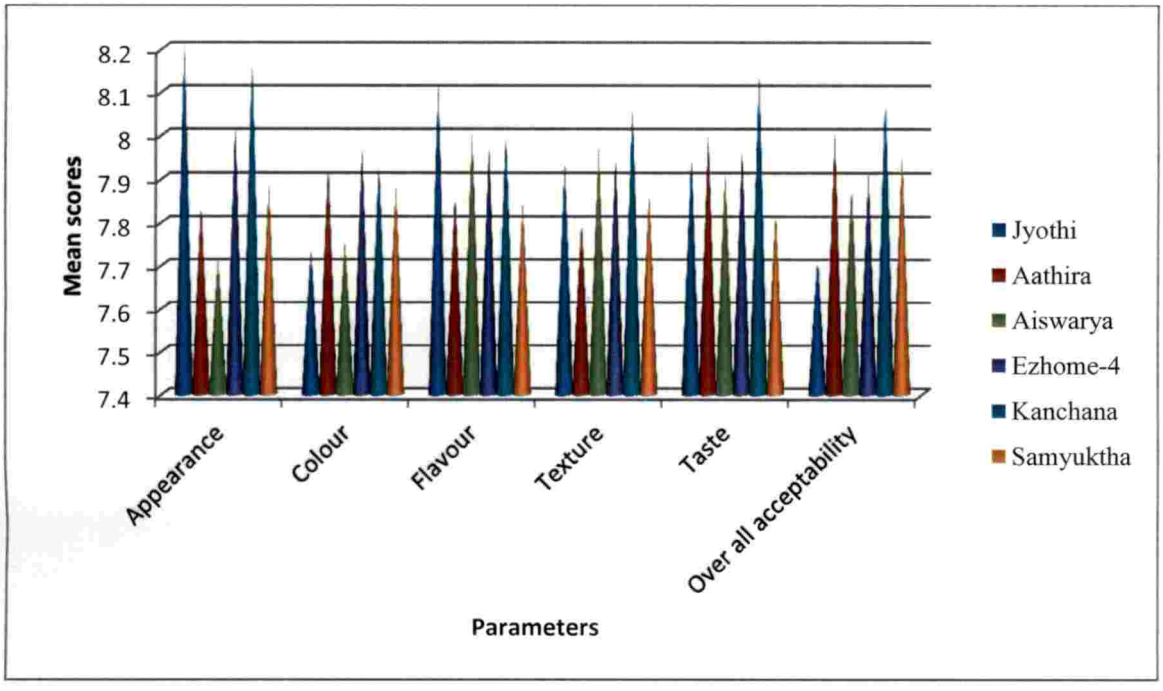


Fig. 30. Mean scores for organoleptic qualities of *idli* prepared with parboiled rice varieties

observed a higher gel length of 61.47 obtained a higher mean score for texture. Higher gel length is an index of cold pasted starch consistency. This might have contributed to the texture of *idli*. In line with this study, Kunhimom (2010) reported that gel consistency contributes a better texture for the prepared product. According to Chandhni (2015) Prathyasha obtained a higher gel length and found it as most suitable for preparation of *idli*.

In parboiled samples, *Kanchana* variety obtained highest mean scores for most of the quality attributes. Lakshmi (2011) reported that *idli* prepared from parboiled rice flour of *Jyothi* variety obtained the highest mean score for different quality attributes. Soubhagya *et al.* (1991) observed that the variety having an amylose content of 22 per cent and above either raw or parboiled were suitable for *idli* preparation, while low amylose and waxy rice yielded hard and sticky textured *idli*. Kumar *et al.*, (2012) observed that *idli* prepared with low polish rice achieved significantly lower scores for appearance and colour, compared with *idli* prepared using highly polished rice. However, *idli* quality was influenced by rice variety and degree of polishing. Among the red rice varieties, *Aiswarya* and *Kanchana* were the most suitable varieties for preparation of *idli* with both raw and parboiled samples.

Idiyappam is a traditional Kerala breakfast dish mainly prepared with rice flour. The highest mean scores for *idiyappam* prepared with raw rice flour was observed in *Ezhome-4* and *Samyuktha*. Lakshmi (2011) observed a higher mean scores for *idiyappam* prepared with parboiled *Jyothi* variety. *Idiyappam* prepared with parboiled rice flour of *Ezhome-4* obtained highest mean score in all quality attributes. Sajeev *et al.* (2015) observed a mean score of 8.06 for overall acceptability of *idiyappam* prepared with black rice. According to Sridevi *et al.* (2015) observed mean scores of 6.36 and 6.14 for *idiyappam* prepared with white and black rice flour respectively. According to Lakshmi (2011) higher water solubility index may influence the texture of *idiyappam*. Yousaf *et al.* (2017) reports that high water solubility index is an indicator of good starch digestibility as it implies the extent of gelatinisation and dextrinisation. In line with this the

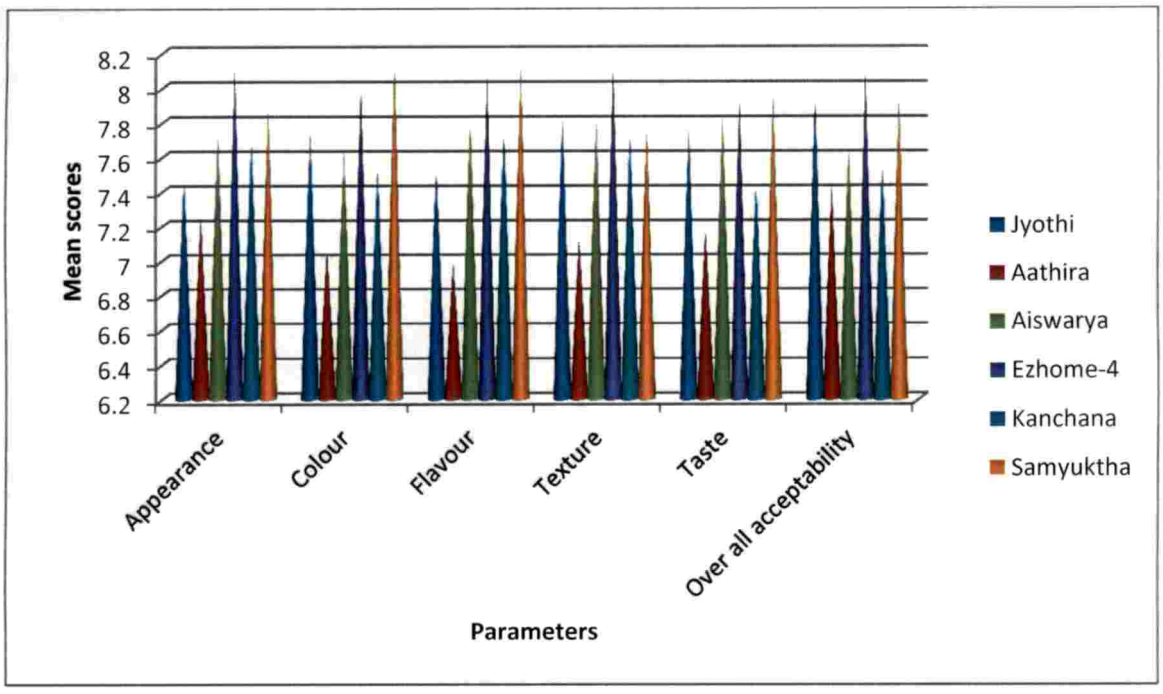


Fig. 31. Mean scores for organoleptic qualities of *idiyappam* prepared with raw rice varieties

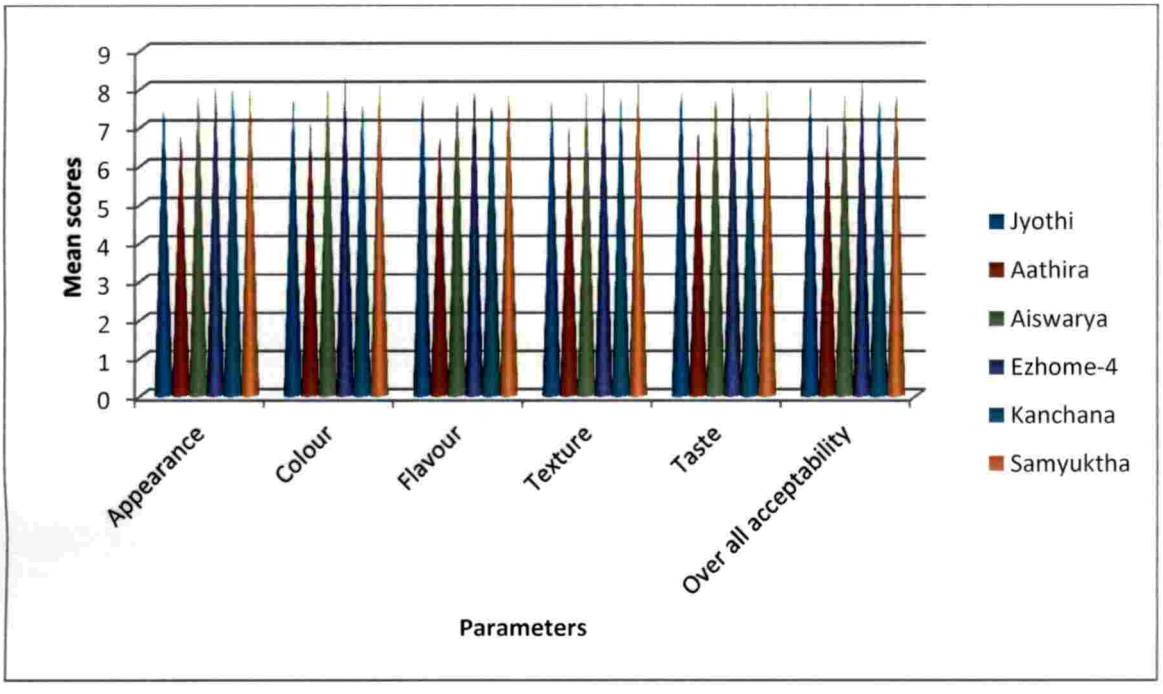


Fig. 32. Mean scores for organoleptic qualities of *idiyappam* prepared with parboiled rice varieties

highest water solubility index of 0.57 was observed in *Ezhome-4* variety, and *idiyappam* prepared with *Ezhome-4* obtained highest mean scores for all quality parameters in the present study.

SUMMARY

6. SUMMARY

The present study entitled 'Quality evaluation of KAU red rice (*Oryza sativa* L.) varieties' was conducted with the objective to assess the effect of parboiling on the physical, biochemical, nutritional, cooking and organoleptic qualities of KAU red rice varieties. The study was also aimed to assess the suitability of these rice varieties for the preparation of selected traditional food products.

KAU released red rice varieties namely *Kanchana* (PTB 50), *Aiswarya* (PTB 52), *Aathira* (PTB 51), *Samyuktha* (PTB 59) and *Ezhome-4* were collected from Regional Agricultural Research Station, Pattambi and Regional Agricultural Research Station, Pilicode respectively. Commonly used red rice variety *Jyothi* was kept as the control and was collected from Agricultural Research Station, Mannuthy. The selected rice varieties were parboiled by hot soaking process. The raw and parboiled rice varieties were milled and various physical quality attributes were assessed. The organoleptic qualities of raw and parboiled cooked rice and suitability for the preparation of *idli* was also carried out. Milled raw and parboiled rice were powdered and the suitability for the preparation of *idiyappam* was assessed.

Physical qualities of rice like milling per cent, head rice recovery, thousand grain weight, volume weight, grain shape and size were determined. Milling per cent among raw red rice varieties varied from 62.76 to 76 per cent, and in parboiled samples it ranged from 67.66 to 77.33 per cent. The highest milling per cent was observed in *Ezhome-4* in both raw and parboiled samples. Among red rice varieties, head rice recovery ranged from 49.32 to 59.15 per cent in raw rice varieties. In parboiled samples the highest head rice recovery was observed in *Ezhome-4* (62.86%) and the lowest was in control variety *Jyothi* (53.66%). In raw red rice varieties, highest thousand grain weight of 26.64 g was observed in *Kanchana* and the lowest of 22.96 was in *Aiswarya*. In parboiled

samples, thousand grain weight was in the range of 25.33g (*Ezhome-4*) to 31.01g (*Jyothi*).

Among raw red rice varieties volume weight ranged from 13.87mm3 (*Aathira*) to 11.84mm3 (*Aiswarya*). In parboiled samples, volume weight ranged from 11.93mm3 (*Samyuktha*) to 14.17mm3 (*Aathira*). In raw samples, grain length and grain width varied in the range of 5.63mm to 9.45mm and 2.08mm to 2.89mm respectively. In parboiled samples, it varied in the range of 5.60mm to 9.22mm and 2.29mm to 3.16mm. Among red rice varieties, the highest L/B ratio of 3.24 and 2.98 was observed in control variety *Jyothi* both raw and parboiled samples. Parboiling improves milling quality due to the hardness imparted to the kernels because of gelatinization of starch.

In raw red rice varieties, the highest bulk density of 0.72g/ml was observed in varieties *Aathira* and *Ezhome-4*. In the case of parboiled samples the highest bulk density was observed in *Kanchana* (0.66g/ml). Water absorption index in raw red rice flour was found to be the highest in *Aiswarya* (25.61) and the lowest in *Samyuktha* (22.46). In parboiled rice flour, a decrease in water absorption index was observed and in the range of 22.04 (*Ezhome-4*) to 23.71 (*Aathira*). The decrease in water absorption index may be due to the modification of starch granules by heating and parboiling process. In raw red rice flours water solubility index was in the range of 0.45 (*Aathira*) to 0.57 (*Ezhome-4*). In parboiled samples, an increased water solubility index was observed ranging from 0.54 (*Jyothi*) to 0.61 (*Ezhome-4*). This may be due to the high amount of damaged starch present in parboiled rice flour to imbibe and hold more water. The highest syneresis per cent was observed in *Samyuktha* after 12th day of study in both raw and parboiled samples.

Samyuktha showed a low gelatinization temperature and varieties *Ezhome-4*, *Aathira*, *Jyothi*, *Kanchana* and *Aiswarya* have intermediate gelatinization temperature when treated with alkali. In parboiled samples, all six varieties shown an intermediate gelatinization temperature. Rice moisture content

during soaking and extent of heating during steaming increase the degree of starch gelatinization. The cooking time taken by the rice varieties varied from 20.33 minutes (*Samyuktha*) to 27 minutes (*Ezhome-4*) in raw samples. In parboiled varieties, cooking time varied from 28.33 minutes (*Samyuktha*) to 37.66 minutes (*Aiswarya*). Parboiled rice has longer cooking time due to the strong cohesion between the endosperm cells which are tightly packed.

In raw red rice varieties, water uptake was in the range of 8.7ml (*Ezhome-4*) to 7.39ml (*Samyuktha*). An increased amount of water uptake was observed in parboiled samples which was ranged from 8.83.ml (*Samyuktha*) to 12.80ml (*Ezhome-4*). Parboiling changes the absorptive capacity of rice and radically alters the hydration characteristics. In raw samples the highest volume expansion ratio was recorded in *Ezhome-4* (5.43) variety and the lowest was recorded in *Aiswarya* (4.38). The highest volume expansion was observed in *Jyothi* (5.70) in parboiled samples and the lowest was in *Samyuktha* (4.77). The highest amylose content of 24.90 per cent was observed in *Aathira* and the lowest was in *Samyuktha* (23.23%) in raw red rice varieties. Among parboiled rice varieties highest amylose content was observed in *Ezhome-4* (24.54%) and the lowest was in *Samyuktha* (23.03%). Amylose content is less in parboiled samples than non-parboiled samples because of the starch solubilisation and leaching of the amylose molecules into the surrounding water during soaking and subsequent steaming during parboiling.

The highest gel length was observed in *Samyuktha* (62.21mm) variety among the raw samples and the lowest was in control variety *Ezhome-4* (55.76mm). In parboiled samples the highest gel length of 51.33mm was observed in *Aiswarya* and the lowest of 24.66mm was observed in control variety *Jyothi*. A decrease in gel consistency was observed after parboiling. This may be due to decrease in starch content after parboiling resulting in less gelatinisation and further a decrease in gel consistency. In raw samples grain elongation ratio varied from1.47 (*Samyuktha*) to 1.79 (*Aiswarya*). In parboiled samples the highest grain elongation ratio was recorded in *Kanchana* (1.61) and the lowest was in

Samyuktha (1.43). Decrease in grain elongation after parboiling may be due to the stronger structure of rice starch as a result of gelatinization process. Most of the physical and cooking qualities of the selected varieties were comparable with *Jyothi*.

The highest moisture content in raw rice was observed in *Aiswarya* (12.5%) and the lowest was in *Jyothi* (10.5%). A slight decrease in moisture content was observed after parboiling. The starch content of rice varieties was assessed and found that among red rice varieties the highest starch content of 70.50 g/100g was observed in *Aiswarya* rice variety in raw samples. The lowest starch content of 65.83 g/100g was observed in control variety *Jyothi*. A decrease in starch content was observed after parboiling and which ranged from 62.40g/100g (*Kanchana*) to 67.43g/100g (*Ezhome-4*). The decrease in starch content might be due to formation of amylose-lipid complexes during hydrothermal process.

Among raw red rice varieties, highest protein content was observed in *Ezhome-4* (5.50g/100g) and the lowest in *Samyuktha* (4.70g/100g). The highest protein content in parboiled samples was noticed in *Samyuktha* (3.75g/100g) rice variety and the lowest in control variety *Jyothi* (3.12g/100g). Soaking causes proteins to sink into the compact mass of gelatinized starch making it less extractable. Therefore, a considerable decrease in protein content was observed in parboiled samples. The highest fat content in raw samples was noticed in *Aathira* (0.48g/100g) rice variety and the lowest in *Samyuktha* (0.31g/100g). Among parboiled samples the highest fat content was observed in *Aathira* rice variety (0.35g/100g) and the lowest in *Samyuktha* (0.24g/100g).

The fibre content of raw rice varieties were determined and found that the highest fibre content of 0.31g/100g was noticed *Ezhome-4* and *Samyuktha*. The lowest fibre content was observed in control variety *Jyothi* (0.18g/100g). The highest fibre content in parboiled samples was noticed in *Kanchana* (0.34g/100g) rice variety and the lowest was in control variety *Jyothi* (0.23g/100g). The highest

thiamine content in raw rice varieties was reported in *Aiswarya* (0.08mg/100g) and the lowest of 0.060mg/100g was recorded in control variety *Jyothi* and *Samyuktha* (0.060mg/100g). A slight increase in thiamine content was observed in the present study after parboiling. This is may be due to the diffusion of thiamine in the germ and pericarp during parboiling. In parboiled samples the highest thiamine content was observed in control variety *Jyothi* (0.087mg) and the lowest in *Samyuktha* (0.070mg/100g).

The calcium content of raw rice varieties was determined and found that the highest calcium content was observed in *Kanchana* (5.76mg/100g) and the lowest in *Aiswarya* (4.90mg/100g). Among raw red rice varieties the zinc content was observed in the range of 1.09mg/100g (*Jyothi*) to 1.32mg/100g (*Aathira* and *Kanchana*). In parboiled rice varieties, the highest zinc content was noticed in *Samyuktha* (1.35mg/100g) and the lowest in *Jyothi* (1.25mg/100g). A slight increase in calcium and zinc content was observed in all the rice varieties after parboiling.

The highest iron content in raw rice varieties was noticed in control variety *Jyothi* (0.61mg/100g) which increased to 0.65mg/100g on parboiling. The highest phosphorus content was observed in *Aiswarya* (131.96mg/100g) and the lowest was in *Aathira* (127.60mg/100g). An increased phosphorus content was observed after parboiling which was ranged from 129.93mg/100g (*Aathira*) to 132.60mg/100 (*Aiswarya*). The mineral contents parboiled samples are higher than raw samples in the present study. This is might be due to the migration of bran components into the endosperm during hydrothermal treatment.

In vitro digestibility was above 72 per cent for all the rice varieties. The highest *in vitro* digestibility in raw rice varieties was observed in *Aathira* (79.06%) and the lowest was in *Ezhome-4* (72.46%). The highest starch digestibility in parboiled samples was noticed in *Aathira* (76.90%) and the lowest was in *Ezhome-4* (70.06%). A significant decrease was noticed in starch digestibility after parboiling in the present study. This is may be due to the

tendency of gelatinized starch during parboiling to undergo retrogradation upon cooling leading to resistant starch formation in parboiled rice grain, it decrease and subsequent starch digestibility. The bran oil content of rice varieties was assessed and found that among raw red rice varieties the highest oil content was noticed in *Samyuktha* (2.10g) and the lowest was in control variety *Jyothi* (1.26g). In parboiled samples the highest oil content was observed in *Aathira* (2.16g) and the lowest was in *Aiswarya* (1.86g) and control variety *Jyothi* (1.86g).

Acceptability of traditional food products prepared with rice varieties namely table rice, *idli* and *idiyappam* was evaluated. The highest mean score for over all acceptability of table rice prepared with raw rice was noticed in *Jyothi* (7.60) with a mean rank score of 4.31. Lowest mean score for over acceptability was recorded in *Samyuktha* (6.71) with a mean rank score 1.84. The mean rank score for overall acceptability of table rice prepared with parboiled rice varied from 7.77 (*Kanchana*) to 6.84 (*Samyuktha*) with a mean rank scores of 4.91 and 1.94 respectively. All six varieties except *Samyuktha* was found to be highly suitable for table rice in both raw and parboiled forms.

Among raw red rice varieties the highest mean rank scores for over all acceptability of *idli* was noticed in *Kanchana* (8.04) and the lowest was in *Samyuktha* (7.68) with a mean rank scores of 3.70 and 2.57. The overall acceptability for *idli* prepared with parboiled rice obtained a mean scores ranged from 8.08 (*Kanchana*) to 7.71 (*Jyothi*) with a mean rank scores of 4.03 and 2.73. The overall acceptability for *idiyappam* prepared with raw rice flour obtained a highest mean score of 8.08 in *Ezhome-4* and the lowest was in *Aathira* (7.42) with a mean rank scores of 4.53 and 2.57 respectively. The highest mean score for overall acceptability of *idiyappam* prepared with parboiled rice flour was noticed in *Ezhome-4* (8.22) and the lowest was in *Aathira* (7.04). All rice varieties were found to be suitable in the preparation of *idli* and *idiyappam* in both raw and parboiled forms. *Kanchana* was found to be most suitable variety for preparation of *idli*. For *idiyappam*, *Ezhome-4* was found to be the best.

Varietal differences highly influence grain quality characteristics of rice. In the present study, variation in different physical and cooking qualities was observed among varieties. Parboiling improved milling qualities and desirable cooking qualities in parboiled rice varieties. Nutritional qualities were comparable with control variety *Jyothi*, which is the most commonly used rice variety in Kerala. Hence, *Aathira*, *Aiswarya*, *Ezhome-4*, *Kanchana* and *Samyuktha* can be popularised among rice farmers specifying their suitability for table rice. The suitability of these rice varieties for traditional food product development was also very high. The knowledge on rice grain qualities of different varieties and their suitability for products can be transferred to farming community to promote end use specific cultivation.

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APPENDICES

APPENDIX I

Score card for the organoleptic evaluation of rice and rice flour based products

Name:

Food product: Date:

Sl. No.	Parameters	Rice varieties					
		1	2	3	4	5	6
1.	Appearance						
2.	Colour						
3.	Flavour						
4.	Texture						
5.	Taste						
6.	Overall acceptability						

9 point hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like or dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature

APPENDIX II

RECIPES FOR THE PREPARATION OF RICE AND RICE FLOUR BASED PRODUCTS

1. COOKED RICE

Ingredients:

Rice – 100g
Water – As required

Procedure:

Add washed rice to sufficient amount of boiling water. Cook it well. After cooking, strain the excess water to get the cooked rice.

2. *IDLI*

Ingredients:

Rice – 200g
Black gram dhal (white) – 100g
Salt – 1 ½ tbsp.
Oil – (for greasing the pans)

Procedure:

Wash and soak the rice and dhal separately for four to six hours. After draining grind rice and dhal separately into a smooth and frothy paste. Mix the ground rice and dhal together into a batter. Mix salt and set aside in a warm place for 8-9 hours or overnight for fermentation. Grease the iddli holder well and fill each of them with 3/4 of batter. Steam cook iddlis on medium flame for about 10 minutes or until done.

3. IDIYAPPAM

Ingredients:

Roasted rice flour – 200g
Hot water – as required
Salt – to taste
Grated coconut – 100 g

Procedure:

Salt is added to rice flour and kneaded well with boiling water. The prepared dough is pressed through a "*sevanazhi*" and steamed using a steamer for 8 to 10 minutes.

QUALITY EVALUATION OF KAU RED RICE (*Oryza sativa* L.) VARIETIES

By
REVATHY G. NADH
(2016-16-105)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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(FOOD SCIENCE AND NUTRITION)

Faculty of Agriculture

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2018

ABSTRACT

The present study entitled 'Quality evaluation of KAU red rice (*Oryza sativa* L.) varieties' was conducted with the objective to assess the effect of parboiling on the physical, biochemical, nutritional, cooking and organoleptic qualities of KAU red rice varieties. The study also aimed to assess the suitability of these rice varieties for the preparation of selected traditional food products.

Milling per cent among raw red rice varieties varied from 62.76 per cent (*Aathira*) to 76 (*Ezhome-4*) per cent and in parboiled samples ranged from 67.66 per cent (*Aiswarya*) to 77.33 (*Ezhome-4*) per cent. The highest milling per cent was observed in *Ezhome-4* both raw and parboiled samples. An increase in milling per cent was observed in all the varieties after parboiling. Among red rice varieties head rice recovery ranged from 49.32 per cent (*Aiswarya*) to 59.15 per cent (*Ezhome-4*) per cent in raw samples. In parboiled samples the highest head rice recovery was observed in *Ezhome-4* (62.86%) and the lowest was in control variety *Jyothi* (53.66%). There was no significant variation among red rice varieties in thousand grain weight and were comparable with *Jyothi*. In parboiled samples an increase in thousand grain weight was observed.

Among raw red rice varieties volume weight ranged from 13.87mm3 (*Aathira*) to 11.84mm3 (*Aiswarya*). The highest volume weight in parboiled samples was observed in *Aathira* (14.17mm3) and the lowest was in *Samyuktha* (11.93mm3). Among red rice varieties the highest L/B ratio 3.24 and 2.98 was observed in control variety *Jyothi* both raw and parboiled samples. All the selected varieties were of lower grain length than control variety *Jyothi*. All varieties showed an increase in major physical quality parameters after parboiling.

In raw red rice varieties the highest bulk density of 0.72g/ml was observed in varieties *Aathira* and *Ezhome-4*. In the case of parboiled samples highest bulk density was observed in *Kanchana* (0.66g/ml). Water absorption index in raw red rice flour was found to be highest in *Aiswarya* (25.61) and the lowest was in *Samyuktha* (22.46). In parboiled rice flour the highest water absorption index was

observed in *Aathira* (23.71) and the lowest was in *Ezhome-4* (22.04). In raw red rice flours, water solubility index in the range of 0.45 (*Aathira*) to 0.57(*Ezhome-4*). The highest water solubility index of 0.61 was observed in *Ezhome-4* in parboiled samples and the lowest was in control variety *Jyothi* (0.54). The highest syneresis per cent was observed in *Samyuktha* after 12th day of study in both raw and parboiled samples.

In raw samples *Samyuktha* showed a low gelatinisation temperature index. Varieties *Ezhome-4*, *Aathira*, *Jyothi*, *Kanchana* and *Aiswarya* showed intermediate gelatinisation temperature index. In parboiled samples, all six varieties shown intermediate gelatinization temperature as the grains were swollen and collar incomplete and narrow. The cooking time taken by the rice varieties varied from 20.33 minutes (*Samyuktha*) to 27 minutes (*Ezhome-4*) in raw samples. In parboiled varieties, cooking time increased which varied from 28.33 minutes (*Samyuktha*) to 37.66 minutes (*Aiswarya*). In raw red rice varieties water uptake was in the range of 8.71ml (*Ezhome-4*) to 7.39ml (*Samyuktha*). In parboiled samples an increase in water uptake was observed with the highest in *Ezhome-4* (12.80ml) variety and lowest in *Samyuktha* (8.83ml) variety.

Volume expansion in raw samples ranged from 5.43 (*Ezhome-4*) to 4.38 (*Aiswarya*). In parboiled samples it was ranged from 5.70 (*Jyothi*) to 4.77 (*Samyuktha*). The highest amylose content of 24.90 per cent was observed in *Aathira* and the lowest was in *Samyuktha* (23.23%) in raw red rice varieties. Among parboiled rice varieties highest amylose content was observed in *Ezhome-4* (24.54%) and the lowest was in *Samyuktha* (23.03%). Gel length of different raw samples ranged from 62.21mm (*Kanchana*) to 55.76mm (*Ezhome-4*). In parboiled samples it was ranged from 51.33mm (*Aiswarya*) to 24.66mm in control variety *Jyothi*. In raw samples grain elongation ratio was varied from1.47 (*Samyuktha*) to 1.79 (*Aiswarya*). No significant variation in grain elongation ratio was observed. A decrease in grain elongation ratio was observed in parboiled samples with the highest in *Kanchana* (1.61) and the lowest in *Samyuktha* (1.43).

The highest moisture content in raw rice was observed in *Aiswarya* (12.5%) and the lowest was in *Jyothi* (10.5%). The highest moisture content in parboiled samples was observed in *Aiswarya* (11.56%) rice variety and the lowest was in control variety *Jyothi* (9.70%). In raw samples starch content was varied from 70.50g/100(*Aiswarya*) to 65.83 (*Jyothi*). In parboiled samples it was ranged from 67.43g/100g (*Ezhome-4*) to 62.40g/100g (*Kanchana*). Among raw red rice varieties highest protein was observed in *Ezhome-4* (5.50g/100g) and the lowest was in *Samyuktha* (4.70g/100g). The highest protein content in parboiled samples was noticed in *Samyuktha* (3.75g/100g) rice variety and the lowest was in control variety *Jyothi* (3.12g/100g). The fat content of different raw samples was in the range of 0.24/100g (*Samyuktha*) to 0.35g/100g (*Aathira*). Among parboiled samples the highest fat content was observed in *Aathira* rice variety (0.48g/100g) and the lowest was in *Samyuktha* (0.31g/100g).

In raw samples highest fibre content of 0.31g/100g was noticed in *Ezhome-4* and *Samyuktha*. The control variety *Jyothi* obtained lowest fibre content in both raw and parboiled samples.

The highest thiamine content in raw rice varieties was reported in *Aiswarya* (0.08mg/100g) and the lowest of 0.06 was recorded in control variety *Jyothi* and *Samyuktha* (0.060mg/100g). In parboiled samples the highest thiamine content was observed in control variety *Jyothi* (0.087mg) and the lowest was in *Samyuktha* (0.070mg/100g). The calcium content of raw rice varieties was determined and found that the highest calcium content was observed in *Kanchana* (5.76mg/100g) and the lowest was in *Aiswarya* (4.90mg/100g). The highest calcium content in parboiled samples was reported in *Kanchana* (6.06mg/100g) and the lowest was in *Ezhome-4* (5.50mg/100g).

Among raw red rice varieties the highest zinc content was observed in *Aathira* (1.32mg/100g) and *Kanchana* (1.32mg/100g) and the lowest was in control variety *Jyothi* (1.09mg/100g). In parboiled rice varieties, the highest zinc content was noticed in *Samyuktha* (1.35mg/100g) and the lowest was in *Jyothi*

(1.25mg/100g). In both raw and parboiled samples highest iron content of 0.61mg/100g and 0.65mg/100g was observed in control variety *Jyothi* and the lowest of 0.39mg/100g and 0.43mg/100 was observed in *Kanchana* rice variety. The phosphorus content of raw red rice varieties was estimated and found that the highest value was observed in *Aiswarya* (131.96mg/100g) and the lowest was in *Aathira* (127.60mg/100g). In parboiled samples the highest was reported in *Aiswarya* (132.60mg/100g) and the lowest of 129.93 was observed in *Aathira* variety.

The highest *in vitro* digestibility in raw rice varieties was observed in *Aathira* (79.06%) and the lowest was in *Ezhome-4* (72.46%). The highest starch digestibility in parboiled samples was noticed in *Aathira* (76.16%) and the lowest was in *Ezhome-4* (70.06%). The bran oil content of rice varieties was assessed and found that among raw red rice varieties the highest oil content was noticed in *Samyuktha* (2.10g) and the lowest was in control variety *Jyothi* (1.26g). In parboiled samples the highest oil content was observed in *Aathira* (2.16g) and the lowest was in *Aiswarya* (1.86g) and control variety *Jyothi* (1.86g).

From organoleptic evaluation of products it was found that all the selected varieties were suitable for table rice. Rice variety *Kanchana* was found to be the most suitable variety for the preparation of *idli*. For the preparation of *idiyappam* *Ezhome-4* was found to be the most suitable variety. From the present study it was found that quality attributes of selected red rice varieties were comparable with control variety *Jyothi*. All the varieties showed an increase in physical quality parameters after parboiling. All the selected red rice varieties are suitable for the preparation of traditional food products. The information on grain quality characteristics can be utilised to popularise these red rice varieties specifying the product suitability.