QUALITY ANALYSIS OF PRE-RELEASE RICE CULTURES OF KAU

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DECLARATION

I hereby declare that this thesis entitled **"Quality analysis of pre-release rice cultures of KAU"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university of society.

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CERTIFICATE

Certified that this thesis entitled **"Quality analysis of pre-release rice cultures of KAU"** is a record of research work done independently by Ms. Sugeetha.T.S (2008-16-104) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

g	gram
mg	milligram
mm	millimeter
ml	milliliter
%	per cent
Kcal	kilo calories
KPa	kilo pascal
min.	minutes
°C	degree celsious
Fig.	Figure
et al	and others
Na	Sodium
P	Phosphorus
K	Potassium
Fe	Iron
Ca	Calcium

INTRODUCTION

INTRODUCTION

Rice (Oryza Sativa) is the queen of cereals and is one of the most important food crops in the world. It forms the staple diet of 2.7 billion people and is grown in all the continents except Antarctica. It occupies an area of 150 million ha, producing 573 million tones paddy with an average productivity of 3.83 tones/ha (Bhashyam et al., 2006).

Rice is a predominant staple food for 17 countries in Asia and Pacific, nine countries in North and South America and eight countries in Africa. Rice cultivation is of immense importance to food security in Asia, where more than 90 per cent of the global rice is produced and consumed.

Today, rice is the staple food of more than 3 billion people in the world and is an important non–staple food for another 2 billion. Ninety five per cent of world rice production and consumption is in Asia. More than 2 billion people in Asia alone derive 80 per cent of their calories from rice (Khatoon and Prakash, 2007).

Rice is the world's leading food crop. Global annual production of rice during 2009 was 432 million tones. India produced 99.37 million tones of rice in the same year (http://businessrediff.com).

FAO (2007) reported that rice and rice products constitute the main staple for people in more than half of the world. The demand for production of rice with high quality in the global market has remarkably increased in recent years.

Rice is a plant of Asian origin. The history of rice cultivation probably dates back to the antiquity and has probably been the staple food and the first cultivated crop in Asia. The earliest record of rice domestication in the world comes from Non Nok Tha in Thailand, which dates back to 3500 BC (Prasad, 1999).

Quality of rice can be influenced by many parameters like physical, cooking, nutritional and organoleptic qualities. Quality is the degree of excellence possessed by the grain (Srivastava, 1997). It depends upon geographic conditions, nutritive value, palatability, appearance and cooking qualities.

Ge et al. (2005) reported that the rice breeders are focusing on efforts to improve rice grain quality. The complex trait of rice grain quality is the sum total of number of component traits, including appearance, cooking and eating quality and nutritional quality.

Good quality rice varieties are preferred by consumers and producers alike. Improvement in grain quality that do not lower yields will generally benefit all rice growers and consumers by lowering the cost of production of better quality rice (Roy et al., 2009).

There is heavy demand for good grain quality in national as well as in international market. In order to tap the full potential of export market, timely supply of quality standard grains is highly essential (Singh et al., 2004). Quality rice also fetches higher price for the farmers (Das et al., 2007).

Rice has been the staple food of Keralites from ancient time and will continue to be like in the near future also. Even though a number of varieties are advocated for cultivation; only selected varieties become popular and establish among farmers as well as end users, mainly due to their quality characteristics. Hence a study has been taken up to assess the major quality parameters of pre–released rice varieties of Kerala Agricultural University, which will be beneficial to the breeders as well as to the consumers of the State. The objectives of the study are:

1. To assess the physical characteristics of selected pre – release rice varieties.
2. To determine the cooking qualities of selected pre – release rice varieties.
3. To estimate the nutritional composition of selected pre – release rice varieties.
4. To assess the organoleptic qualities and
5. To identify the superior variety based on the above mentioned parameters.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The literature pertaining to the study entitled "Quality analysis of pre –release rice cultures" is reviewed under the following headings.

2.1 Rice production in India
2.2 Processing of rice
2.3 Quality parameters of rice
2.4 Value addition of rice
2.5 Biotechnological aspects of rice

2.1 Rice production in India

Latin (2000) opined that rice is the staple food of Indian population and is mainly consumed in the form of whole grains.

Rice is the staple food for more than 65 per cent of Indian population and is a source of livelihood for about 100 million of rural households (Naik et al., 2006).

In India, rice has been cultivated since ancient times and it is the most important and extensively grown food crop, occupying about 44.8 million hectares of land (Singh et al., 2006). The authors also reported that rice occupies a pivotal place in Indian agricultural and is the staple food for more than 70 per cent of population and is a source of livelihood for about 120 – 150 million rural households. It accounts for about 43 per cent of total food grain production and 55 per cent of cereal production in the country.

India is an important centre of rice cultivation and is the largest rice growing country, while China is the largest producer of rice. India produced 99.37 million tones of rice in 2009. In the previous year it was 96.69 million tones of rice (business.rediff.com).

In India, rice is grown in almost all the states. The area growing rice in Kerala has fallen in 276,000 hectares (680,000 acres) in 2006 from 801, 700 hectares in 1980.

According to Oghbaei and Prakash (2010) both raw and parboiled rice are used very widely by Indian population in the cooked form as staple cereals.

2.2 Processing of rice

2.2.1 Drying

Drying is the process of simultaneous heat and moisture transfer. It is the removal of excess moisture from the grains. Proper drying results in increased storage life of the grains. In India, three methods are used for drying the paddy grains namely: sun drying, mechanical drying and chemical drying.

According to Chen and Chu (2001) a low dry temperature (40° - 50°C) is much better than a high temperature (60° - 70°C). Drying at lower temperatures reduces the broken kernels and improves the taste of cooked rice.

Iwata (2001) reported that drying reduces grain water content to 15 per cent. The temperature for drying is kept below 40° C and the drying process takes about 48 hours to remove moisture uniformly. The author also reported that too high temperature and excessively short drying process both negatively influence appearance, quality and palatability.

Aquerreta et al. (2007) stated that drying temperature at 60° C give the best quality of rice.

2.2.2 Milling

Milling is the process where in the rice grain is transformed in to a form suitable for human consumption. Rice is mostly consumed as cooked whole grain. Milling technology is therefore geared to obtain maximum out turn of milled rice and to reduce breakage to the minimum.

Rice is an important world wide agricultural commodity. The rice milling process yields about 15 per cent broken rice kernels (Bond, 2004).

The appearance of milled rice is very important from market point of view (Das et al., 2005).

Veenapal and Pandey (2000) found that, milling conditions alter its physico–chemical characteristics and consumer acceptability.

According to Pillaiyar (2004) the husk and bran are the only fractions that are removed during milling.

The milled rice from stored paddy gets influenced by the initial conditions of the grain storage period and environmental conditions, which may result in quality changes (Archana et al., 2007).

Singh et al. (1999) reported that milling causes breakage due to sun cracks in grain. Rice breakage also depends upon the type of mill, moisture content, grain size and shape. The optimum moisture content of paddy for milling is 13 to 14 per cent. At this moisture content maximum shelling with minimum breakage is achieved.

2.2.3 Parboiling

Parboiling is a hydrothermal treatment given to paddy prior to milling for improving its milling quality and nutritive value (Bhattacharya, 2004).

Parboiling is one of the important tools of value addition. More than fifty per cent of paddy produced in India is parboiled (Naik et al., 2006).

Parboiling is a process for eliminating the pre – existing defects in the grains. The nutrient status of rice is enhanced by this technique (Pillaiyar, 2004).The author also reported that the endosperm hardness is improved, colour is changed, and cooking and eating qualities are modified in parboiling.

Unnikrishnan and Bhattacharya (1995) stated that parboiling of paddy requires three steps viz. soaking, steaming and drying. Recently, the use of fluidization techniques (Soponronnarit et al., 2006) and ohmic heating (Sivashanmugan and Aranazhagan, 2008) to parboil rice have been reported.

The study conducted by Kaddusmiah et al. (2002a) and Naik et al. (2006) reported that from the commercial and consumer point of view, the main quality criteria of parboiled rice are optimum milling yield, maximum head rice, minimum broken grain, negative internal fissuring, uniform grain size, desirable colour and aroma.

Parboiled rice is the staple food in southern Asian countries such as India, Srilanka, Pakistan, Nepal and Bangladesh (Bhattacharya, 2004; Roy et al., 2007).

Parboiling resulted in an increase in the ash content for all the paddy rice cultivars. This indicates that there is diffusion of minerals in to the rice kernels during the steeping and steaming process (Gujral and Singh, 2001; Bhattacharya, 1995).

Parboiling resulted in inward diffusion of water soluble vitamins and other bran components (Juliano and Hicks, 1996).

As per the view of Otebayo et al. (2001); Bhattacharya (2004); Derycke et al. (2005); Heinemann et al. (2005) and Kim et al. (2006) parboiled rice had harder kernels upon drying, improved milling yields, more translucent, less sticky, higher retension of minerals, and water soluble vitamins, increased health promoting starch fraction (resistant starch) and longer shelf life.

According to Kaddusmiah et al. (2002a) the main quality criteria of parboiled rice is optimum milling yield, maximum head rice, minimum broken grain, uniform grain size, desirable colour and aroma.

Parboiled rice is most often used in the industrial and food service markets because of its ease of preparation, durability and stability to cooking (Vegas, 2008).

Parboiled rice becomes discoloured (turns light yellow to amber) due to maillard type non enzymatic browning and the diffusion of hull and bran pigments into the endosperm during soaking (Lamberts et al., 2006). The paste viscosity decrease has been attributed to the decreased swelling ability and water binding capacity of the partially gelatinized starch in parboiled rice (Soponronnarit et al., 2006).

Thirupathi et al. (2000) reported that, paddy soaked for 30 minutes and steamed under 123.60 KPa pressure for 22 minutes gives maximum rice yield, breaking hardness value, translucence index and minimum cooking time.

Oghbaei and Prakash (2010) reported that the main scope of parboiling treatment, that may take from few hours to few days, is to wet the inner kernel and favour the migration of nutritionally valuable substances from the hull to the kernel. Hence there are differences in nutritional composition of raw and parboiled rice.

2.3 Quality parameters of rice

Rice grain quality is multi–dimensional. Physical characteristics influence appearance, chemical characteristics influence cooking quality and eating quality is influenced by both (Chen and Chu, 2001).

According to Goyal and Sharma (1998) the over all assessment of a food grain is determined by its physical, physico – chemical, nutritional, milling, cooking, processing, eating and storage qualities besides economic values.

Veenapal and Pandey (2000) reported that quality of rice depends upon its physical quality which means cleanliness, soundness and absence of foreign materials.

Rice quality depends on a combination of several physico – chemical properties of the rice grains. Depending on dietary habit and cooking method, the definition of quality varies from region to region in the world.

Badawi and El – Hisswy (2001) reported that the chemical composition, starch, protein, lipid, ash and mineral content, crude fibre and moisture content affect the nutritional quality of rice grain, including cooking and eating quality.

Srivastava (1997) opined that a scientific examination of quality should be done for various factors like moisture content, presence of foreign matters, immature and damaged grains, red rice and varietal purity. Therefore, according to Rao (1997), it is only through proper analysis of quality aspects that the grade of paddy and consequently its quality can be determined.

Quality parameters like hulling, milling, head rice recovery, amylose and protein content were influenced by nutrient management practices (Saha et al., 2007).

Improvement in quality parameters of rice due to combined application of organic sources of nutrient along with inorganic fertilizer was also reported by Dixit and Gupta (2000).

Grain quality of aromatic rice is of prime importance in breeding programmers all over the world because it decides the consumer preference and thus acceptability of a variety (Khush, 2000).

The scented rice has high premium value in national as well as in international market due to unique aroma and quality (Yadav et al., 2007).

2.3.1. Physical characteristics

The majority of farmers and consumers depend on visual characters for the differentiation and evaluation of rice varieties. Visual characters comprise grain dimension, grain appearance and chalkiness. Grain dimension comprises grain length, width, shape and thickness (Badawi and El – Hissewy, 2001).

The physical matrix of raw and parboiled rice is also different due to preprocessing and these may alter the bio accessibility of nutrients (Oghbaei and Prakash, 2010).

Physical characteristics of grain are found to be major determinants of quality. These are decided by factors like, thousand grain weight, grain dimensions, moisture percentage, milling yield, head rice yield and L/B ratio.

Veni and Rani (2008) reported that the grain size and shape of rice are important characteristics, which determine the consumer preference as well as the commercial success of a variety. These greatly affect the head rice recovery and the milling quality.

Badawi and El – Hissewy (2001) reported that the milled rice is classified on the basis of average length in to four groups: short, medium, long and extra long.

The length – breadth ratio is used in classifying the shape. Dela and Khush (2000) opined that the length breadth ratio (L/B) falling between 3.00-5.5 is acceptable, when the length is more than 6mm.

Singh et al. (2000) reported that varieties with lower L/B ratio showed a higher loss of ash content than those having higher L/B ratio.

Grain weight provides the information about the size and density of the grain. Uniform grain weight is important for consistent grain quality (Yadav et al., 2007).

Grain shape is expressed as the ratio between grain length and width; it is classified in to round, bold, medium and slender (Badawi and El – Hissewy, 2001).

The average head rice recovery of Indian rice varieties were between 20 to 40 per cent (Poonam et al., 2000).

Elbert et al. (2001) observed a high head rice yield, if drying temperature and initial moisture are low.

According to Nirmala (1997) thousand grain weight is considered to be a function to kernel size and its density, and this determines milling quality.

Study by Nandini (1995) and Sheena (1997) reported that the thousand grain weight of high yielding varieties were found to be in higher when compared to traditional varieties.

According to Badawi and El – Hissewy (2001) grain appearance depends on endosperm opacity and the amount of chalkiness. Chalkiness reduces the milling recovery of rice grain by increasing the breakage ratio and by decreasing the head rice output.

Swelling capacity/seed is the ratio of the final to the initial volume or weight of the rice (Sood et al., 2002). According to Taira and Shoji (2000) swelling capacity and viscosity are reduced with increase in amylose and nitrogen contents of rice varieties.

The water absorption capacity, as reflected by the swelling ratio, is significantly lower for parboiled rice than for raw rice cooked for same period and was reported by Varadharaju et al. (2001).

2.3.2. Cooking characteristics

Cooking quality is very important for the acceptance of a variety by the consumer and is determined in terms of volume expansion ratio, water uptake and kernel length after cooking (Das et al., 2005).

Amylose/Amylopectin ratio, gelatinization temperature, volume expansion, elongation and water uptake largely determine the cooking quality of rice (Malik and Chaudhary, 2001).

Dela and Khush (2000) found that cooking and eating characteristics are largely determined by the properties of the starch that makes up to 90 per cent of milled rice. Juliano (1998) stated that gelatinization temperature and amylose content are important starch properties which influence cooking and eating characteristics, others being kernel elongation and aroma.

In a study conducted by Varadharaju et al. (2001) it was found that cooking time of raw rice samples ranged between 22 and 25 minutes and those of parboiled rice samples ranged between 30 to 33 minutes.

Cooking time is important as it determines tenderness of cooked rice as well as stickness to a great extent (Anon, 1997).

Volume expansion may be in either length or breadth. Water uptake is another important index of cooking quality of rice and is directly related to volume expansion. Water uptake is the only character with positive influence on kernel elongation (Malik and Chaudhary, 2001).

Singh et al. (1997) concluded that lengthwise expansion of rice on cooking without increase in girth is considered as highly desirable trait in higher quality rice.

Higher volume expansion after cooking is a desirable trait preferred by consumers. Nandini (1995) reported that volume expansion after cooking was found to be influenced by the water uptake and the expansion was higher in high yielding rice varieties when compared to traditional varieties. The author also reported that volume expansion was found to be decreased significantly in case of parboiled rice samples, when compared to raw rice samples.

Unnikrishnan and Bhattacharya (1995) reported that, ageing through storage results in higher head rice yield, greater water absorption and volume expansion during boiling,

Varadharaju et al. (2001) observed that there was no appreciable change in water uptake due to the method of parboiling of paddy, but there is reduction in water uptake in parboiled rice over the raw rice.

Higher the gruel loss, greater will be the nutrient loss. Hence decreased gruel loss is advantageous from the nutritional point of view. The loss of solids in cooking water generally serves as good parameters for the assessment of cooking quality of rice (Hirannaiah et al., 2001).

Gel consistency is a reliable index for cooked rice texture. Cooked rice with hard gel consistency hardens faster than that with a soft one. Rice with soft gel consistency cook tender and also remain soft after cooking (Bansal et al., 2006).

Gel consistency is a good measure of the gel viscosity of milled rice and determines softness after cooking (Badawi and El – Hissewy, 2001). The authors also revealed that gelatinization temperature determines water uptake and the time required for cooking. Similar reports were also observed by Marshall et al. (1993).

Gelatinization temperature is the temperature at which rice starch begins to melt (gelatinize) and take up water. Rice has a gelatinization temperature of 65-85° C (Aquerreta et al., 2007).

According to Sabouri (2009) and Yadav et al. (2007) gelatinization temperature is a physical trait responsible for cooking time and the capacity to absorb water during the process of cooking and the temperature at which starch irreversibly loses its crystalline order during cooking.

Kaddusmiah et al. (2002b) reported that gelatinization temperature is the range of temperature where in at least 90 per cent of the starch granules swell irreversibly in hot water with loss of crystalline and birefringence. The gelatinization temperature of rice varieties may be classified as low (55 to 69° C), intermediate (70 to 74° C) and high (> 74° C) (Dela and Khush, 2000).

Elongation ratio is the ratio of the dimension of the cooked and uncooked rice or elongation ratio is defined as the ratio of the length of cooked rice grains to the length of milled rice grains. Elongation is the expansion of rice grains upon cooking. According to Dela and Khush (2000) length wise expansion without increase in width is considered as highly desirable trait.

Elongation ratio is an important parameter for cooked rice. If rice elongates more length wise it gives a finer appearance and if expands girth wise, it gives a coarse look (Anon, 1997). Ward and Martin (2009) reported that all the types of rice become longer when they are cooked.

Amylose content is the most important parameter to assess eating and cooking quality of rice (Das et al., 2005 and Shi et al., 2005).

According to Malik and Chaudhary (2001) amylose determines the cohesiveness, tenderness, volume expansion and appearance of cooked rice.

The amylose content which determines flakiness/stickiness of cooked rice (Dey and Hussian, 2009). Rice with a high amylose content (25 - 30 %) tends to cook firm and dry, where as rice with an intermediate amylose content (20 – 25 %) tends to be softer and stickier and rice with a low amylose content (<20 %) is generally quite soft and sticky (Yadav et al., 2007).

Rashmi et al. (2000) observed that many of the cooking and eating characteristics of milled rice are influenced by the ratio of two kinds of starches – amylose and amylopectin in the rice grain.

The amylose–amylopectin ratio is the main factor for classifying rice in to waxy and non–waxy (Badawi and El – Hissewy, 2001).

According to Ward and Martin (2009) cooking qualities of the rice are generally associated with the grain variety. Milled white rice is composed of approximately 93 per cent starch (amylose and amylopectin), approximately 7 per cent protein and approximately 0.5 per cent lipids.

2.3.3. Nutritional Composition

The nutritional composition of rice grain is a major parameter influencing the quality of rice grains. The chemical composition, starch, protein, lipid, ash and mineral content and crude fibre and moisture content all affect the nutritional quality of rice grain.

Rice is primarily a high energy or high calorie food. It supplies almost 60 per cent of the dietary energy (Singh et al., 2006).

Rice is one of the most widely grown crops and main staple food for about half the world's population. It provides 21 per cent of global human per capita energy and 15 per cent of per capita protein. Although rice protein ranks high in nutritional quality among cereals, its content is modest (Maclean et al., 2002).

Rice provides about 75 per cent of the calorie and 55 per cent of the protein in the average daily diet of the people (Anon, 2002). According to Bhattacharjee et al. (2002) rice contributes over 20 per cent of the total energy intake of man.

Meena et al. (2009) reported that rice is a key food for human nutrition because it supplies starch, protein and the majority of micro nutrients to humans, particularly in Asia. In addition, it is also a good source of carbohydrates and B complex vitamins.

Rice is reported to be a moderate source of protein. However, rice is considered to be a major source of dietary protein in Indian diets, the quantity and type of protein are important factor in rice nutrition.

Juliano (1998) reported that protein is the second highest constituent of the milled rice. It makes a fundamental contribution to nutritional quality.

Rice accounts for 21 and 41 per cent of global energy and protein respectively and is the dominant staple food for 15 countries in Asia and Pacific (Kennedy and Burlingame, 2003).

According to Singh et al. (2006) and Ward and Martin (2009) the protein content of milled rice is generally around 7 per cent, but can reach up to 12 per cent if the soil has a high nitrogen load.

Rai (2009) reported that among cereal proteins, rice protein is biologically the richest by virtue of its high true digestibility (88%) and relatively better net protein utilization.

Devi et al. (1997) stated that proteins present in food are a mixture of several fractions and each fraction differs in its solubility, amino acid composition and digestibility.

According to Athmaselvi et al. (2001) the covering layers, namely pericarp, testa or seed coat and aluerone layer are fibrous and contain phytin, which interface in absorption of protein and makes rice different to cook,

According to Badawi and El – Hissewy (2001) starch is the principal constituent of rice, comprising about 90 per cent of the total dry matter of milled rice starch consists mainly of two molecular types; amylose and amylopectin. Starch is extremely important as a macronutrient, as it is a complex carbohydrate and an important energy source in our diet (Gill et al., 2003).

According to Juliano (1998), starch is the major constituent of rice. Starch, a polymer of glucose occurs in the endosperm as compound polyhedral granules, three to ten microns in size (Kaddusmiah et al., 2002b).

Amylose content and quantitative and qualitative differences in the various non – carbohydrate constituents, such as lipid and protein affect pasting characteristics of starches (Mangala et al., 1999). Liang and King (2003) found that the addition of charged amino acid affected the pasting characteristics of rice starch.

Kaddusmiah et al. (2002b) observed that starch granules are family hydroscopic; therefore, the moisture content of the rice grain readily changes with a change in storage temperature or relative humidity. The authors also stated that the hydrodynamic volume of starch increases because of irreversible swelling ie, gelatinization.

Moisture content of rice is a very important factor which markedly affects several facts of rice quality.

Grain should be dried to 14 per cent approximately to avoid losses due to breakage in milling. Kunze (2001) stated that moisture re-adsorption causes starch to expand and produce compressive stresses that can lead to fissured grain which usually break during milling.

The fat content of rice is low (2.0 to 2.5 per cent) and much of the fat is lost during milling (Singh et al., 2006).

Milled rice contains a lipid level of approximately 1.1g/100g or 5 per cent dry basic (Anon, 2001; Zhou et al., 2003; Kitta et al., 2005). In addition, most lipids in rice consist of long chain fatty acids such as linoleic (18: 2) and linolenic (18: 3) acids (Khongseri, 2003, Kitta et al., 2005). These lipids are absorbed as the surface of starch granules and bound inside (Zhou et al., 2003).

Rice is reported to be a moderate source of fibre and minerals. Most of the crude fibres of rice are in the bran and outer layers; for this reason brown rice has higher crude fibre content than milled rice (Badawi and Ei – Hissewy, 2001).

Mirko et al. (2001) reported that cereals form quantitatively most important sources of dietary fibre in many industrialized countries. According to Devi and Geervani (2000) varietal difference has no implication on increase in dietary fibre content as a result of parboiling.

Rice is reported to be moderate source of minerals. According to Athmaselvi et al. (2001) the phytin content interfer the absorption of minerals like calcium and iron. Santha and Arulmozhi (2001) reported that parboiled rice retains more vitamins and minerals and is more nutritious than raw milled rice.

According to Sangha and Sachdeva (1999) rice is a fair source of vitamins and poor source of minerals.

According to Rai (2009) rice is a principal source of B vitamins (Thiamine and riboflavin) and minerals (Fe and Ca).

Studies of Koga et al. (2001) suggested that climatic factors affect mineral composition particularly Na, P and K content of polished rice.

2.3.4 Organoleptic qualities

Quality refers to degree of excellence and suitability for specific utility of the plant product. Initially in the beginning, the main aim of rice research was to maximize the yield but in recent past it has been shifted to quality rice production also. This is because high yielding varieties or hybrids take off smoothly if they possess consumer acceptability (Babu et al., 2007).

Sensory evaluation is the key factor for determining the shelf life of many food products (Broody, 2003).

Organoleptic quality viz., eating quality consists of judging quality of foods by means of human sensory organs – eye, nose and mouth. Sensory evaluation is designed to reflect common preference, to maintain the quality of food at a given standard, for the assessment of process variation, cost reduction, product improvement, new market development and market analysis (Manay and Swamy, 2002).

Cultivar quality is the most important determinant for market quality. According to Chen and Chu (2001) the consumer demand for rice quality involves rice appearance and eating quality. Rice appearance includes grain size, shape and chalkiness. Eating quality includes: appearance, flavour, taste, hardness, stickness and over all acceptability of cooked rice.

Many factors influence the palatability of rice (Bett–Garber et al. 2001; Champagne et al., 2004).

Palatability characters are the main indication of consumer preference for the different rice varieties. They are affected by factors such as variety, grain dimension, and degree of milling, cooking properties and cooking methods. Palatability characters differ from place to place according to consumer habits (Badawi and El–Hissewy, 2001).

In a study conducted by Varadharaju et al. (2001) it was found that, there were appreciable changes in colours due to the method adopted for parboiling. The authors also stated that parboiling alters the colour of rice to varying extent.

Malik and Chaudhary (2001) reported that the aroma in rice is a preferred character. Although aroma in rice is genetically controlled by a single recessive gene, it is also highly influenced by environmental factors.

Extensive studies on rice revealed that among 200 identified volatile compounds, only a few contribute to the characteristic aroma of rice (Jezuseek et al., 2002).

Consumer acceptance of speciality rice such as Jasmine rice was driven by its prominent sensory characteristic including flavour and aroma (Suwansri et al., 2002).

According to Ramesh et al. (2000) the factors affecting texture and eating quality of cooked rice include genetic variation eg:., varietal differences in amylose content, pasting characteristics, protein content, alkali degradation and gelatinization properties.

According to Fumio (2000) the main ingredients that affect the taste of rice are protein, starch, water and fat content.

The sensory properties of cooked rice are subtle and numerous studies emphasize texture and cooking quality (Meullenet et al., 2000; Hirannaiah et al., 2001; Sermat and Meullenet 2001; Mohapatra and Bad 2006; Leelayuthsoontorn and Thipayarat, 2006).

2.4. Value addition of rice

Value addition is a terminology used to define the processing of biological produce. Through processing, the value of commodities can be increased by converting them to different products by using conventional or modern processing techniques, there by the storage of the produce is enhanced.

According to Nirmal et al. (1999) value added products are raw or processed commodities whose values has been increased through the addition of ingredients or process that make them more attractive to the buyer or more valuable by the consumer. Value added processing makes an important contribution to agricultural development and farm income of the country.

According to Joseph (2001) value addition to food products chiefly in terms of cost value is a consequence of acceptability of enhancement.

Foods are perishable commodities and are there for processed to preserve them from deterioration, while providing the consumer with palatable, wholesome, nutritious and tasty food in a convenient form, throughout the year (Anand, 2000).

Food processing is very important for the prosperity of India. Food processing industry helps to avoid post harvest losses of agricultural products in India. The value addition of food production is only 7 per cent compared to 23 per cent in China, 45 per cent in Philippines and 88 per cent in United Kingdom (Mallaya, 2003).

Ray and Athwali (2000) reported that more and more people are going for processed foods and it is estimated that over 10 per cent of total expenditure incurred in the households for foods is spent on processed foods.

Shorab (1995) opined that though food processing was not given due importance in earlier time since last few years a change has taken place in this area. Now-a-days the growth of technology has made many of the basic foods in to processed items and with people opting for life on a fast line, these processed foods has come to the market as a blessing in disguise.

Improved value addition to agricultural crops is necessary to ensure sustainability and prosperity through agriculture. In most of the developed countries, the agricultural produces are processed, packaged and marketed. There is a need for minimally processed food and the food industry is focusing its research on the technologies that offer potential for preserving the wholesomeness of food.

Premnath et al. (2004) reported that increased awareness about sound health and quality life and increased problems of nutritional insecurity among all sections of the society around the globe, particularly the developing countries brought about a sudden shift from food grain production and consumption pattern to diversified and value added production and consumption. Also there is considerable change in the life style of an average Indian due to various reasons viz., urbanization, increase in per capita income, explosion of mass media, and increase in working women's population, security of household labourers as well as technological developments and invasion of consumerism (Nirmal et al., 1999).

Kaur and Kapoor (2002) are of the opinion that fresh foods which are in excess supply during season and storage during the rest of the year is a phenomenon, which invites attention to the development of technologies for appropriate processing and packaging.

2.4.1. Value added rice products

Hicks (1998) reported that the product and by products of rice are utilized by man in hundreds of ways.

Rice and rice based products derived from rice grain and rice flour include parboiled rice, quick cooking rice and ready to eat convenience foods, rice flavours, rice starch, rice cakes and puddings, baked products, breakfast cereals and expanded rice products, extrusion – cooked and puffed rice snacks, noodles, pasta, baby foods, fermented foods and beverages, pet foods and bran products. (Juliano, 2003).

Menezes et al. (1999) suggested the method for freeze drying Basmati rice. This process involves cooking of Basmati rice for one minute (retains maximum aroma).

Ready to eat breakfast cereals is many forms quickly became popular. Enrichment and fortification also enhance and also became a common practice for breakfast cereals (Vaclavik and Christian, 2005).

Sheela (2004) reported that the expanded rice is a traditional convenience food widely consumed in India either as such or with jaggery, roasted bengal gram and shredded vegetables and spices. The product is mostly produced in home or cottage sector by skilled artisans.

Flaked or brown rice and parboiled milled rice may be converted to puffed rice by heating in hot air or roasting in hot sand (Villareal and Juliano, 1997).

Wong et al. (2000) produced Anka (read rice produced by fermenting rice with Monasous spp.), which is used as traditional Chinese medicine to promote digestion and blood circulation. The authors suggested that it is also used to suppress hypertriglyceridaemia and hyperlipidaemia in humans.

Rice vinegar results from the completion of the rice starch fermentation and is a traditional Japanese and Chinese product (Iwasaki, 1987)

Broken grain is used in the food industry to produce preserves, alcohol, special types of vodka and beer (Zelensky, 2001).

Rice wines are fermented alcoholic drinks produced from cereals. The maximum percentage of alcohol in original pure rice wine is below 20 per cent, usually 15-16 per cent. Moderate consumption of wine may decrease the risk of heart disease especially in middle aged and elderly men. It also enhances the body's absorption of iron (Anon, 2003).

According to Yoshizawa and Kishi (1995) rice is the only cereal substrate in Japanese rice wine such as sake.

Extrusion offers the feasibility of modifying functional properties of food ingredients and provides a wide range of novel and pre-cooked and technical foods. Usually extruded products are processed with cereal flours (Karolein, 2004).

Jha and Prasad (2003) reported that extrusion is a popular means of preparing snack foods and ready-to-eat breakfast cereals using starch based raw materials. The raw materials such as flours of rice, wheat, corn, oat can be incorporated into a formulation with other ingredients to change the physical, chemical, sensory and nutritional properties of the product.

Rice noodles are an important part of the diet in many oriental countries (His-Meilai, 2001).

Ready to eat pre-cooked pasta or rice based dish containing a sauce which does not require cooking and just treated or toasted or grilled was suggested by Comparini (1999).

Variables with different starch levels specific to a particular product or preparation have been identified for making many kinds of processed products (Rani and Krishnaiah, 2001).

According to Ganesan (2004) rice starch is a special product used as a major component of face powder. The fine particle size of rice starch makes it especially suitable for cosmetic use.

Nair et al. (2004) reported that the rice of Navara is used as an effective therapeutic measure for various degenerative conditions and rejuvenative purposes. It is also useful to improve muscle strength and bulk of muscle where there is wasting due to various reasons.

Hyllstam et al. (1998) proposed the method of processing rice to provide quick cooking rice.

Commercially produced quick cooking rice is a potentially effective vehicle for micronutrient fortification. Iron, calcium, zinc, thiamine and folate can be added during the production process. Types of fortificants used however must be chosen carefully, since they can affect the fortification process, product sensory acceptability, and shelf life (Chifpan et al., 2005).

The magnitude of the less economic valued broken rice as a resource for value added products suggests a strong economic impact on the entire rice industry. The market potential for rice ingredients in processed foods is enormous (Sac-Eaw et al., 2007).

According to Rohrer and Siebenmorgen (2004) rice bran, a byproduct of rice milling is a constituent (approximately 10%) of the whole rice grain and consists of the bran layers (pericarp, seed coat, nucellus and aleurone) and the germ.

Rice bran typically contains 16-32 per cent oil. Three major fatty acids, palmitic, oleic and linoleic make up more than 90 per cent of the total fatty acids (Saunders, 1990).

Hargrove and Keith (1994) reported that due to rice bran's overall composition, nutritional profile, functional characteristics and apparent hypoallergenicity, it has many applications in a healthy diet. It is high in dietary fibre and low in saturated fat.

The high antioxidant capacity of light brown rice bran is mainly attributed to its lipophilic antioxidants, which include gamma-oryzanol, tocopherols and tocotrienols (Wu et al., 2004).

According to Rao (2004) both the bran and oil from rice bran have a range of bioactive phyto-chemicals in reducing the risk of chronic degenerative diseases.

Pszezold (2001) reported that use of rice based ingredients will reduce the amounts of fat absorbed during frying resulting in development of crisp rice products which are shelf stable, does not require cooking and lastly has health benefits associated with rice bran and oil derived from rice.

Rice bran oil (RBO) is generally considered to be one of the highest quality vegetable oils available in terms of its cooking qualities, shelf life and fatty acid composition (Sayre and Saunders, 1990).

Compared to other plant oils, RBO is relatively stable to oxidation due to its higher saturation. Relatively lower levels of linolenic acid as well as the presence of many phenolic compounds and vitamin E derivatives are very efficient in reducing low density lipo protein and total serum cholesterol (Mazza, 1998; Yu et al., 2006).

2.5 Biotechnological aspects of rice

The latest high-tech speciality varieties such as "Saffron rice", "yellow rice" or "golden rice" may contribute to solving problems related to ammonia and vitamin A deficiency.

Biotechnological tools have opined the way for incorporating foreign genes and improving the nutritional and quality features of the rice grain. There are great opportunities for developing nutritionally superior rice varieties, such as "yellow rice" (Chaudhary and Tran, 2001).

Genetic enrichment of rice with iron, zinc and other minerals and vitamins may benefit billions of people at no extra cost of them. The latest "high-tech" version of rice may look like saffron rice. This golden rice has been genetically engineered to contain beta-carotene, the precursor to vitamin A, together with a healthy dose of iron (Sharma, 2007).

Golden rice was first presented in 2000 as a rice variety that was genetically engineered (GE) in a laboratory to produce provitamin A (beta-carotene). The genetically engineered rice was expected to overcome vitamin A deficiency, which can result in blindness and even death and occurs predominantly in developing countries (Christoph, 2005).

According to Beyer et al. (2002) golden rice was genetically engineered contain beta-carotene, not present in standard rice, to combat the widespread vitamin A deficiency and ensuring blindness in the children of the developing world. Golden rice would thus seem to be an advance in the fight against vitamin A deficiency in rice eating population.

Some of the beneficial aspects regarding rice achieved through biotechnological approach as reported by Dutta and Bous (2000) were increase in iron content through ferritin genes, introduction of heat stable phytase gene to break down phytic acid, an antinutritional factor in rice, increase in lysine content of rice by genetic engineering, production of transgenic rice containing beta -carotene.

Studies conducted by Paola et al. (2001) reported that to increase iron bioavailability, thermo tolerant phytase can be introduced into the rice endosperm.

Shih and Paigle (2000) observed that various enzymes like amylase, followed by glucoamylase, cellulase and xylanase were treated to protein enriched rice flour for the production of protein isolates. The authors stated that this technique raised protein content of rice flour to 91 per cent from 49 per cent.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Quality analysis of pre-release rice cultures of KAU" encompasses an assessment of various parameters like physical characteristics, cooking characteristics, nutritional composition and organoleptic qualities of eight pre-release rice cultures evolved by Rice Research Stations of Kerala Agricultural University located at Moncompu and Kayamkulam.

3.1 Materials selected

Eight pre-release rice cultures were selected for the study. Cultures selected are presented in table 1

Table.1 Rice cultures selected

Sl No.	Varieties
1	M-108-262-1
2	MO6-10-KR
3	MO8-20-KR
4	MO-87-5
5	MO-95-1
6	OM-2
7	OM-3
8	OM-4

Two kilogram of the above rice cultures were collected from the respective Rice Research Stations of KAU such as Moncompu and Kayamkulam and were processed by two methods viz raw milled and parboiled milled.

The processed rice cultures were stored in airtight steel containers for various laboratory studies.

3.2 Quality parameters selected

Rice grain quality is multi-dimensional. It can be influenced by many parameters like physical, cooking, nutritional and organoleptic qualities. Quality is the degree of excellence possessed by the grain.

Different quality parameters studied on the materials were:

1. Physical characteristics
2. Cooking characteristics
3. Nutritional composition and
4. Organoleptic qualities.

Under each parameter, a number of indicators are reported to influence the quality of rice and are listed below.

3.2.1 Physical characteristics

Physical characteristics of the rice grains were found to be a major determinant of quality and acceptability of rice. Different indicators ascertained under physical characteristics are

a. Colour

Colour of the rice cultures were ascertained by direct observation.

b. Size

For determining size, the rice samples were classified into three classes i.e., extra bold, bold and medium bold according to the method given by FAO (1970).

c. Shape

For determining shape, the rice samples were classified into three classes ie, slender and long grain rice, bold and medium grain rice and round and short grain rice according to the method suggested by FAO (1970).

Slender, long grain rice - L/B ratio >3.0

Bold, medium grain rice – L/B ratio 2.0-3.0

Round, short grain rice – L/B ratio <2.0

d. Length and Width

Grain length has long been used in most rice breeding programmes as a characteristic for classifying rice varieties. Grain width is an important factor in determining the grain shape and weight. The grain length and width were determined by taking the length and width of ten grains drawn randomly using a measuring scale.

e. Length-Breadth ratio (L/B ratio)

Length of the grain is measured in its greatest dimension, width along the ventral side. Length- breadth (L/B) ratio of rice cultures were calculated as per the method outlined by Pillaiyar and Mohandoss (1981a).

f. Thousand grain weight

Thousand grain weight of rice cultures were determined by weighing one thousand rice grains randomly selected (Sindhu et al., 1975).

An electronic balance was used for recording thousand grain weight.

g. Swelling index

Swelling index of rice cultures was determined by the method of Sharma et al. (2004).

h. Swelling capacity/seed

Swelling capacity is the ratio of the differences between final and initial volume to the number of seeds. It was determined as per the method suggested by Sharma et al. (2004).

i. Hydration capacity/seed

Hydration capacity/seed is the ratio of the differences between final and initial weight to the number of seeds. It was determined as per the method suggested by Sharma et al. (2004).

3.2.2 Cooking characteristics

Cooking quality is very important for acceptance of a variety by the consumers and it ultimately decides eating quality. Different indicators ascertained under cooking characteristics are furnished below.

a. Optimum cooking time

Optimum cooking time was estimated as per the method suggested by Bhattacharya and Sowbhagya (1971).

b. Volume expansion

Volume expansion may be in either length or breadth. It was estimated as per the method suggested by Pillaiyar and Mohandoss (1981b).

c. Elongation ratio

Elongation ratio is an important parameter for cooked rice. It is the ratio between the length of cooked grain and that of the raw grain. It was measured as per the method suggested by Pillaiyar and Mohandoss (1981b).

d. Water uptake

Water uptake is a measure of the hydration characteristics of rice. It was estimated as per the method outlined by Bhattacharya and Sowbhagya (1971).

e. Gruel loss

The loss of carbohydrates principally starch and non-starch polysaccharides and lipids through the gruel is termed as gruel loss. It was measured as per the method outlined by Sanjiva rao et al. (1952).

f. Gelatinization temperature

Gelatinization temperature is a major determinant of cooking time and water absorption during cooking. Gelatinization temperature was estimated as per the method of Mac Masters (1964).

g. Amylose

Amylose content is a major determinant of the cooking and eating quality. Total amylose content was estimated as per the method of Mc Cready and Hassid (1943).

h. Amylose-amylopectin ratio

Amylose-amylopectin ratio is the main factor for classifying rice into waxy and non-waxy. Amylose-amylopectin ratio of rice cultures were estimated as per the method suggested by Mc Cready and Hassid (1943).

3.2.3 Nutritional composition

The major nutrients analyzed in the raw and parboiled samples are listed below

a. Energy

Energy or calorific value was estimated using Bomb calorimeter as per the method described by Swaminathan (1984).

b. Protein

The nitrogen content of samples was estimated by micro Kjeldahl's wet digestion method. The nitrogen values were multiplied by the factor 6.25 to get the crude protein content (A.O.A.C, 1970).

c. Moisture

Moisture content was estimated by the method of A.O.A.C (1990).

d. Starch

Starch content of the samples was estimated using anthrone reagent described by Sadasivam and Manikam (1992).

e. Crude fibre

Crude fibre content was estimated by the method of Sadasivam and Manikam (1992).

f. Total mineral

Total mineral content was estimated as per the method described by Raghuramalu et al. (1983).

g. Calcium

Calcium was estimated after wet digestion of the sample with triple acid. The triple acid digest was titrated against EDTA (Jackson, 1973).

h. Phosphorus

Phosphorus was estimated after wet digestion of the sample by the Vanadopmolybdate yellow colour method as outlined by Jackson (1973).

i. Iron

The iron content was estimated by the method of Jackson (1973).

j. Thiamine

The thiamine content of the samples was estimated fluorimetrically using the procedure described by Sadasivam and Manikam (1992).

3.2.4 Organoleptic qualities

Organoleptic qualities play an important role in the quality of any food. Organoleptic quality consists of judging quality of foods by means of human sensory organs such as eye, nose and mouth. Palatability characters are the main indication of consumer preference for the different rice cultures.

Manay and Swamy (2002) opined that sensory evaluation plays a vital role in the food industry, because it represents a very unique technique that harness human behavioral instincts of perception, learning, cognition, psychophysis and psychometrics for the evaluation of food quality.

Organoleptic qualities of different cultures of rice, both raw and parboiled were assessed by a selected panel of judges.

3.2.4.1 Selection of judges

A sensory panel is the panel of members who are capable of delivering highly reliable judgements, independent of psychological factors such as bias motivation and individual motivation (Lawless, 1998).

A panel of ten judges, including the staff and students, were selected as the sensory panel for organoleptic evaluation of the rice samples.

These judges were selected through triangle test, as suggested by Mahony (1985). Details are given in Appendix 1

3.2.4.2 Preparation of score card

The score card used for the evaluation of cooked rice is given in Appendix II

The major quality attributes included in the score card were appearance, colour, flavour, taste and doneness.

3.2.5 Selection of superior variety

The superior variety was selected based on cooking, nutritional and organoleptic qualities of rice varieties. Cooking qualities include optimum cooking time, water uptake, elongation ratio, gruel loss and amylose. Nutritional qualities include energy and protein. Organoleptic qualities include over all acceptability of rice samples.

3.2.6 Statistical analysis

Statistical analysis was carried out as follows;

1. Analysis of variance for the comparison of varieties with respect to various quality attributes (Snedecor and Cochran, 1968).
2. Discriminant function analysis to determine the superior variety (Fisher, 1936).

RESULTS

4. RESULT

The Study entitled "Quality analysis of pre-release rice cultures of KAU" was conducted to ascertain the following quality parameters of the raw and parboiled rice varieties.

4.1 Physical Characteristics

4.2 Cooking Characteristics

4.3 Nutritional Composition

4.4 Organoleptic qualities and

4.5 Selection of superior variety.

4.1 Physical characteristics

Size, colour, shape, length, width, L/B ratio, thousand grain weight, hydration capacity, swelling capacity and swelling index were determined to assess the physical characteristics of rice varieties.

Table 2 shows colour and shape of rice varieties.

In the present study, all the varieties were found to be white in colour and bold, medium in shape.

Size of the rice varieties depends on the values of thousand grain weight. In raw rice, the varieties such as MO-87–5 and MO–95–1 were found to be medium bold and others were found to be bold in size. In parboiled rice, the varieties such as MO–87–5 and MO–95–1 were found to be medium bold and the variety OM – 3 found to be extra bold and all others were bold.

Table 2: Shape and colour of rice varieties.

Variety	Shape	Colour
M-108-262-1	Bold, medium	White
MO6-10-KR	Bold, medium	White
MO8-20-KR	Bold,medium	White
MO-87-5	Bold, medium	White
MO-95-1	Bold ,medium	White
OM-2	Bold ,medium	White
OM-3	Bold ,medium	White
OM-4	Bold, medium	White

The data on the length, width and length/breadth ratio of the rice cultures are presented in Table.3. Length/Breadth ratio is the ratio of mean Kernel length to mean Kernel breadth. (Veni and Rani, 2008).

In the present study, the mean length of grain was found to be highest for MO8–20–KR (6.88mm) and lowest for MO–87–5 (5.60mm).

Parboiling decreased the length of the rice varieties. The mean length of grain ranged from 5.8mm to 6.96 mm in raw rice and between 5.40 mm to 6.80 mm in parboiled rice.

The width was found to range from 2.36 mm to 2.76mm in raw rice and 2.23mm to 2.70mm in parboiled rice. The width was found to be highest for the variety OM–3 (2.73) and lowest for the variety MO–95–1 (2.29). Parboiling process was found to decrease the width of the rice varieties.

Table: 3: Length, Width and L/B ratio of rice varieties.

Variety	Length (mm)			Width (mm)			L/B ratio		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	6.13	5.96	6.05	2.67	2.60	2.64	2.29	2.29	2.29
MO6-10-KR	5.83	5.63	5.73	2.60	2.53	2.57	2.24	2.23	2.24
MO8-20-KR	6.96	6.80	6.88	2.40	2.33	2.37	2.90	2.92	2.91
MO-87-5	5.80	5.40	5.60	2.66	2.43	2.55	2.18	2.22	2.20
MO-95-1	6.13	6.10	6.12	2.36	2.23	2.29	2.59	2.74	2.67
OM-2	5.90	5.80	5.85	2.63	2.53	2.58	2.24	2.29	2.27
OM-3	6.03	5.93	5.98	2.76	2.70	2.73	2.18	2.19	2.19
OM-4	6.00	5.60	5.80	2.73	2.63	2.68	2.19	2.13	2.16
Mean	**6.09**	**5.90**		**2.60**	**2.49**		**2.35**	**2.38**	

L/B ratio varied between the different varieties of rice. The highest L/B ratio was recorded for the variety MO8–20–KR (2.91) and lowest for the variety OM–4 (2.16). In raw rice, the L/B ratio ranged between 2.18 to 2.90 and in parboiled rice it was between 2.13 to 2.92.

The data on the thousand grain weight of rice varieties are depicted in Table 4.

Table: 4: Thousand grain weight of rice varieties

Variety	Thousand grain weight (g)		
	Raw rice	Parboiled rice	Mean
M-108-262-1	23.34	24.08	23.71
MO6-10-KR	21.16	22.37	21.76
MO8-20-KR	21.48	22.76	22.12
MO-87-5	18.00	18.99	18.49
MO-95-1	16.63	17.50	17.07
OM-2	20.66	22.80	21.73
OM-3	22.81	25.90	24.36
OM-4	22.07	23.19	22.63
Mean	**20.77**	**22.19**	

	CD Values	F values
Varieties	0.441	265.82 **
Treatments	0.221	174.43 * *
VxT	0.624	6.79 **

**Significant at 1% level

Significant difference in thousand grain weight was observed among rice varieties. The highest value for thousand grain weight for raw rice was recorded for the variety M–108-262–1 (23.34) and lowest value observed in MO–95–1 (16.63). In the case of parboiled rice, highest value was noted in variety OM-3 (25.90) and lowest in MO–95–1 (17.50). The thousand grain weight values ranged between 16.63g to 23.34g in raw rice and between 17.50g to 25.90g in parboiled rice varieties.

It was observed that parboiled samples had significantly higher thousand grain weight values compared to raw rice samples. The interaction between variety and processing methods was also found to be significant (F = 6.79**).

The data on hydration capacity, swelling capacity and swelling index of rice varieties are depicted in Table 5.

The hydration capacity per seed was found to range from 0.006 to 0.009 in raw rice varieties and 0.013 to 0.019 in parboiled rice varieties.

There was significant difference between the rice varieties and also between raw and parboiled sample in terms of hydration capacity/seed (F = 23.763**). The interaction between varieties and processing methods was also found to be significant (F = 23.763**)

Swelling capacity per seed was ranged from 0.003 to 0.014 in raw rice and 0.011 to 0.027 in parboiled rice. Highest value for swelling capacity was observed in OM–4 (0.017) and lowest in M–108–262-1 and MO8–20–KR (0.011). There was significant difference between the rice varieties and also interaction between varieties and processing method was found to be significant (F = 114.819**).

In the present study, significant difference in swelling index was observed among rice varieties. Swelling index ranged between 0.10 to 0.51 in raw rice samples and 0.33 to 0.90 in parboiled rice samples. Highest value for swelling index was observed in MO –87–5 (0.65) and lowest in M–108–262–1 (0.29). Significant difference also exist between varieties and processing method applied in terms of swelling index (F = 1199.399**).

Table: 5 Hydration capacity, swelling capacity and swelling index of rice varieties

Variety	Hydration capacity (ml/seed)			Swelling capacity (ml/seed)			Swelling Index		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	0.008	0.016	0.012	0.011	0.011	0.011	0.25	0.33	0.29
MO6-10-KR	0.009	0.019	0.014	0.013	0.014	0.014	0.33	0.43	0.38
MO8-20-KR	0.009	0.015	0.012	0.003	0.011	0.011	0.10	0.63	0.37
MO-87-5	0.007	0.013	0.010	0.014	0.016	0.016	0.44	0.85	0.65
MO-95-1	0.008	0.015	0.011	0.010	0.015	0.015	0.51	0.67	0.59
OM-2	0.009	0.013	0.011	0.008	0.013	0.013	0.24	0.85	0.55
OM-3	0.009	0.018	0.013	0.011	0.012	0.012	0.33	0.43	0.38
OM-4	0.006	0.017	0.011	0.007	0.017	0.017	0.23	0.90	0.57
Mean	**0.008**	**0.016**		**0.010**	**0.017**		**0.30**	**0.64**	
	CD values	F values		CD values	F values		CD values	F values	
Varieties	7.6027	28.564 **		9.9128	42.671 **		1.038	1322.34 **	
Treatments	3.8014	1748.4 **		4.9564	1032.495 **		5.189	17067.19 **	
VxT	1.0752	23.763 **		1.4019	114.819 **		1.468	1199.399 **	

* * Significant at 1% level

4.2 Cooking characteristics

Cooking quality is very important for the acceptance of a variety by the consumers (Das et al., 2005).

The cooking characteristics of the rice varieties were evaluated by determining the optimum cooking time, volume expansion, elongation ratio, water uptake, gruel loss, cooked weight, gelatinization temperature, amylose, amylopectin and amylose amylopectin ratio.

The data on the optimum cooking time and volume expansion of the rice varieties are depicted in Table 6.

The optimum cooking time was found to be significantly different among the varieties (F = 91.04**). It was observed that the variety MO – 87 – 5 took higher cooking time (48.16 min) and variety OM – 2 took lesser time (32.33 min) to cook. In the present study, the optimum cooking time of the raw rice varieties ranged between 20.33 – 32.66 min.

The optimum cooking time was significantly affected by parboiling (F=4625.76**). Parboiling increased the cooking time of rice varieties. The optimum cooking time of the parboiled rice varieties ranged between 44.00 – 69.00 min.

The statistical analysis revealed that the interaction between varieties and processing methods was found to be significant (F = 21.60**) in terms of cooking time.

Volume expansion or kernel expansion is determined from the ratio between the cooked volumes of rice, to that of cooked rice. A comparison of the rice varieties revealed significant difference in volume expansion (F = 25.28**)

Table: 6 Cooking time and volume expansion of rice varieties

Variety	Cooking time (minute)			Volume expansion (ratio)		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	23.00	52.66	37.83	5.53	5.06	5.30
MO6-10-KR	25.00	58.33	41.66	5.43	4.83	5.13
MO8-20-KR	30.66	57.00	43.83	5.36	5.33	5.35
MO-87-5	32.66	63.66	48.16	5.10	4.83	4.96
MO-95-1	26.66	69.00	47.83	5.90	4.76	5.33
OM-2	20.66	44.00	32.33	5.20	5.26	5.23
OM-3	20.33	46.66	33.50	4.83	4.90	4.86
OM-4	24.66	53.33	39.00	5.20	4.63	4.91
Mean	**25.45**	**55.58**		**5.32**	**4.95**	
	CD values	F values		CD values	F values	
Varieties	1.807	91.04 **		0.112	25.28 **	
Treatments	0.904	4625.76 **		5.638	175.99 **	
VxT	2.556	21.60 **		0.159	27.79 **	

* * Significant at 1% level

Higher volume expansion was observed in MO8-20-KR (5.35) followed by MO–95 –1 (5.33). The lowest expansion was observed in OM–3 (4.86) followed by OM–4 (4.91).

The volume expansion for raw rice varieties was in the range, 4.83 to 5.90 and that of parboiled rice varieties, was between 4.63 to 5.33

A significant decrease in volume expansion was observed when rice varieties were parboiled. The mean value of volume expansion for parboiled rice varieties was 4.95 and that of raw rice varieties, was 5.32. The present study also revealed significant interaction between varieties and processing (F=27.79**).

The datas on elongation ratio, water uptake and gruel loss of the rice varieties was presented in Table 7.

Elongation ratio is the ratio between the length of cooked grain and that of raw grain. A significant varietal variation was observed in the elongation ratio of different rice varieties as shown in Table 7. In the present study, the highest elongation ratio was possessed by MO6-10-KR (1.68) and lowest by variety OM-4 (1.51). The elongation ratio of raw rice ranged between 1.50 to 1.62 and that of parboiled rice ranged between 1.54 to 1.74.

Parboiling process significantly increased the elongation ratio of the rice varieties. The mean elongation ratio of parboiled rice was 1.63 and that of raw rice was 1.52. The interaction between rice varieties and processing methods with respect to elongation ratio was also found to be significant (F = 36.50**).

Water uptake is a measure of the hydration characteristics of rice. It was evident from Table 7 that the water uptake ratios of the varieties were significantly

Table: 7 Elongation ratio, Water uptake and Gruel loss of rice varieties

Variety	Elongation ratio			Water uptake ratio			Gruel loss (%)		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	1.54	1.73	1.64	1.28	1.51	1.40	6.90	4.69	5.79
MO6-10-KR	1.62	1.75	1.68	1.32	1.59	1.46	8.49	0.22	4.35
MO8-20-KR	1.50	1.63	1.56	1.27	1.54	1.41	7.06	2.25	4.66
MO-87-5	1.55	1.72	1.64	1.30	1.56	1.43	0.59	0.51	0.55
MO-95-1	1.53	1.55	1.54	1.27	1.62	1.44	2.40	0.24	1.32
OM-2	1.51	1.54	1.53	1.41	1.53	1.47	3.57	1.90	2.74
OM-3	1.50	1.54	1.52	1.33	1.54	1.43	5.97	0.60	3.29
OM-4	1.45	1.58	1.51	1.41	1.64	1.52	4.20	4.20	4.20
Mean	**1.52**	**1.63**		**1.33**	**1.57**		**4.90**	**1.83**	

	CD values	F values	CD values	F values	CD values	F values
Varieties	1.553	142.77 **	7.947	209.95 **	1.038	63.72**
Treatments	7.769	760.28 **	3.973	15179.23 **	5.189	386.49 **
VxT	2.197	36.50 **	1.124	131.73 **	1.468	41.92 **

* * Significant at 1% level

different. Among the rice varieties, OM–4 possessed higher water uptake ratio (1.52) and M–108–262–1 had the lowest (1.40).

When the data was analyzed statistically, significant difference exists between raw and parboiled rice. The mean value of water uptake ratio of raw rice varieties was 1.33 while that of parboiled rice varieties was 1.57. Statistical data also revealed a significant interaction between the varieties and processing method (F = 131.73**).

Gruel loss is considered as an important cooking characteristic of rice.

As evident from Table 7, there was a significant difference among the varieties (F = 63.72**) with respect to gruel loss. Among the eight varieties the percentage of gruel loss was highest in variety M – 108 – 262 – 1 (5.79%) and lowest in MO – 87 – 5 (0.55%).

In the present study, gruel loss was significantly affected by parboiling process. Results focused that gruel loss has been significantly decreased in parboiling. It was also revealed that a significant interaction exists between varieties and processing (F = 41.92**).

The data on cooked weight and gelatinization temperature of rice varieties was depicted in Table 8.

In the present study, a significant difference in cooked weight was observed among rice varieties. The highest cooked weight was possessed by MO8-20-KR (66.80g) and lowest by variety MO-95-1 (46.68g). The cooked weight of raw rice ranged between 48.99 to 79.25g and that of parboiled rice ranged between 40.97 to 55.92g.

Parboiling process significantly decreased the cooked weight of the rice varieties. Mean cooked weight of the parboiled rice was 50.45g and that of raw rice

Table: 8 Cooked weight and Gelatinization temperature of rice varieties

Variety	Cooked weight (g)			Gelatinization Temperature (°C)		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	68.76	49.76	59.26	64.00	67.66	65.83
MO6-10-KR	55.09	53.04	54.06	65.00	67.66	66.33
MO8-20-KR	79.14	54.46	66.80	65.33	68.33	66.83
MO-87-5	79.25	50.99	65.12	64.00	68.33	66.16
MO-95-1	48.99	44.37	46.68	65.33	67.33	66.33
OM-2	71.76	40.97	56.37	62.33	65.66	64.00
OM-3	59.90	54.11	57.00	64.66	65.33	65.00
OM-4	72.56	55.92	64.24	64.00	68	66.00
Mean	**66.93**	**50.45**		**64.33**	**67.29**	

	CD values	F values	CD values	F values
Varieties	0.553	1209.74 **	1.005	6.69 **
Treatments	0.276	14727.49 **	0.502	144.05 **
VxT	0.783	852.97 **	1.422	2.90 *

** Significant at 1% level

* Significant at 5% level

was 66.93g. The interaction between the rice varieties and processing methods was also found to be significant (F = 852.97**).

Gelatinization temperature is the temperature at which the starch in rice begins the process of cooking. At this point the starch granules take up water, swell and lose their crystalline nature.

A significant difference was observed in the gelatinization temperature among the different rice varieties (F = 6.69**). As noticed from the table, the highest value for the gelatinization temperature was observed in variety MO-8-20-KR (66.83^{0}C), and lowest in OM-2 (64^{0}C)

There was a significant difference between raw and parboiled rice varieties (F = 144.05**). The gelatinization temperature of raw rice varieties ranged from 62.33 to 65.33^{0}C and that of parboiled rice varieties ranged between 65.33 – 68.33^{0}C. Significantly higher gelatinization temperature was observed in parboiled rice samples compared to raw rice samples. The interaction between varieties and processing methods was also found to be significant (F = 2.90*)

Table 9 represents amylose, amylopectin and amylose–amylopectin ratio of the rice varieties. Amylose content of rice varieties varied significantly. The highest amylose content (24.58%) was noticed in variety OM-4, which was on par with variety MO6-10-KR (24.29%) while the lowest (21.25%) noted in variety MO-95-1, was on par with variety OM-2 (21.66%) and M-108-262-1 (21.91%).

Rice varieties are grouped on the basis of their amylose content into waxy (0-2%) very low (3-9%) low (10-19%) intermediate (20-25%) and high (>25%). Consumers prefer a rice grain with intermediate amylose content. Among the eight rice varieties studied, all the eight varieties belonged to intermediate amylose group.

Table: 9 Amylose, Amylopectin and Amylose-Amylopectin ratio of rice varieties

Variety	Amylose (%)			Amylopectin (%)			Amylose-Amylopectin ratio		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	21.75	22.08	21.91	56.92	50.62	53.79	0.38	0.43	0.40
MO6-10-KR	24.83	23.75	24.29	52.75	47.91	50.33	0.47	0.49	0.48
MO8-20-KR	22.50	22.08	22.29	55.81	52.09	53.95	0.40	0.42	0.41
MO-87-5	23.33	21.66	22.50	55.82	51.85	53.68	0.42	0.42	0.42
MO-95-1	22.08	20.41	21.25	55.86	51.77	53.82	0.39	0.39	0.39
OM-2	23.75	19.58	21.66	54.38	53.07	53.72	0.44	0.37	0.40
OM-3	23.33	22.08	22.70	55.61	51.05	53.33	0.41	0.43	0.42
OM-4	26.66	22.50	24.58	52.37	50.23	51.30	0.50	0.45	0.47
Mean	**23.53**	**21.77**		**54.90**	**51.08**		**0.43**	**0.42**	

	Amylose CD values	Amylose F values	Amylopectin CD values	Amylopectin F values	Ratio CD values	Ratio F values
Varieties	1.019	11.50 **	1.145	12.06 **	2.890	11.21**
Treatments	0.509	49.67 **	0.572	185.47 **	1.445	5.38
VxT	1.441	5.29 **	1.620	3.82 **	4.087	4.45 **

** Significant at 1% level

A significant decrease in amylose content was observed after parboiling. The mean value of amylose content among the raw rice varieties was 23.53 per cent and that of parboiled rice was 21.77 per cent. The interaction between varieties and processing method was also found to be significant (F = 5.29**)

In the present study, a significant difference in amylopectin content was observed among rice varieties (F = 12.06**). The highest amylopectin content (53.95) was noticed in variety MO8-20-KR, which was on par with variety MO-95-1 (53.82), M-108-262-1 (53.79), OM – 2 (53.72), MO-87-5 (53.68) while the lowest (50.33) noted in variety MO6-10-KR, was on par with variety OM-4 (51.30).

A significant decrease in amylopectin content was observed after parboiling. This might be due to the loss of gluten into the gruel. The mean value of amylopectin content among the raw rice varieties was 54.90 and that of parboiled rice varieties was 51.08. The interaction between the varieties and processing method was also found to be significant (F = 3.82**).

The amylose – amylopectin ratio varied significantly among the different rice varieties (F = 11.21**) (Table 9). The highest ratio was observed in variety MO6-10-KR (O. 48), which was on par with variety OM-4 (0.47) and lowest ratio in variety MO – 95 – 1 (0.39), which was on par with varieties OM-2 and M-108-262-1 (0.40) and MO8-20-KR (0.41).

The amylose – amylopectin ratio ranged between 0.38 to 0.50 per cent in raw rice varieties and between 0.37 to 0.49 per cent in parboiled rice varieties respectively.

When analysed statistically, the data revealed that, there was no significant difference in amylose-amylopectin ratio between the raw and parboiled rice but the interaction between variety and processing method was found to be statistically significant (F = 4.45**).

4.3 Nutritional Composition

The calorific value, protein, moisture, starch, crude fibre, total mineral, calcium, phosphorus, iron and thiamine content of the rice varieties were determined to assess the nutritional composition.

The values of energy and protein content of the rice varieties are presented in Table 10.

The calorific value was found to vary significantly among most of the rice varieties studied. The variety M08-20-KR was found to have highest calorific value (386.17 Kcal) followed by MO–87–5 (375.83 Kcal) and the variety OM–4 was found to have lowest calorific value (364.67 Kcal). The calorific value among the eight rice varieties was found to range between 357 to 383.33 for raw varieties and 372.33 to 389 for parboiled samples.

Parboiling process was found to increase the calorific value of rice varieties significantly. The interaction between the variety and processing method applied was statistically analysed and found out that there was significant difference (F = 23.58**).

Rice is considered to be a major source of dietary protein in Indian diets. Significant difference between the rice varieties was observed in the study, with respect to protein content.

The protein content of raw rice was between 5.60 to 7.12g and that of parboiled rice it was between 6.88 to 10.27g. Highest value of protein content was noted in OM–2 (8.17g) and lowest in OM–4 (6.24g).

Table: 10 Energy and Protein content of rice varieties

Variety	Energy (Kcal/100g)			Protein (g/100g)		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	361.67	374.67	368.17	6.42	7.93	7.18
MO6-10-KR	361.00	381.67	371.33	6.07	7.35	6.71
MO8-20-KR	383.33	389.00	386.17	6.88	7.47	7.18
MO-87-5	370.00	381.67	375.83	6.65	8.40	7.53
MO-95-1	369.00	379.00	374.00	6.53	9.45	7.99
OM-2	362.00	373.33	367.67	6.07	10.27	8.17
OM-3	364.67	382.33	373.50	7.12	7.58	7.35
OM-4	357.00	372.33	364.67	5.60	6.88	6.24
Mean	**366.08**	**379.25**		**6.42**	**8.17**	

	CD values	F values	CD values	F values
Varieties	1.389	188.46 **	0.367	24.59 **
Treatments	0.694	1495.73 **	0.183	378.89 **
VxT	1.964	23.58 **	0.519	23.99 **

** Significant at 1% level

In the present study, it was also noticed that parboiling resulted in increase in protein content of rice. The mean value for parboiled rice was 8.17 g, while that of raw rice was 6.42 g. Significant interaction was observed in protein content between the rice varieties and processing method applied (F = 23.99 **).

The values of moisture and starch content of the rice varieties are presented in Table 11.

In the present study, the moisture content was found to range from 11.73 to 13.37 per cent in raw rice and 12.53 to 13.80 per cent in parboiled rice varieties. Highest moisture content was observed in variety MO–87–5 and MO–95–1 (13.40%) and lowest in variety OM–4 (12.40 %). When analysed statistically, the data revealed significant difference in moisture content among the rice varieties (F = 15.95 **)

A significant increase in the moisture content was observed in parboiled rice samples when compared to raw rice samples. The mean value for raw rice was 12.59 per cent as against 13.30 per cent in parboiled rice. The interaction between the varieties and processing method was also found to be significant with respect to moisture content (F = 10.79 **).

In the present study, the highest value for starch content was recorded in the variety M08–20–KR (76.25%) and the lowest in M06–10–KR (74.63%). In raw rice varieties, starch content ranged between 77.59 to 79.04 per cent and in parboiled rice varieties, the starch content was between 71.66 to 74.18 per cent.

Significant difference was noted among the varieties (F = 7.76**).

Parboiling reduced the percentage of starch content of rice varieties. The mean starch content for parboiled rice varieties was 72.83 per cent and that of raw

Table: 11 Moisture and Starch content of rice varieties.

Variety	Moisture (%)			Starch (%)		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	12.40	13.40	12.90	78.68	72.74	75.71
MO6-10-KR	12.60	13.80	13.20	77.59	71.66	74.63
MO8-20-KR	11.73	13.20	12.47	78.31	74.18	76.25
MO-87-5	13.37	13.43	13.40	78.86	73.37	76.11
MO-95-1	13.07	13.73	13.40	77.95	72.19	75.07
OM-2	13.07	12.80	12.93	78.13	72.66	75.39
OM-3	12.27	13.50	12.88	78.94	73.13	76.04
OM-4	12.27	12.53	12.40	79.04	72.74	75.89
Mean	**12.59**	**13.30**		**78.44**	**72.83**	

	Moisture CD values	Moisture F values	Starch CD values	Starch F values
Varieties	0.275	15.95 **	0.584	7.76 **
Treatments	0.137	109.54 **	0.292	1530.92 **
VxT	0.388	10.79 **	0.826	2.59 *

** Significant at 1% level

* Significant at 5% level

rice varieties was 78.44 per cent. The interaction between the varieties and processing method was found to be significant (F = 2.59*).

Table 12 reveals the values of fibre content and total mineral content of the rice varieties.

It was observed that the fibre content of rice varieties differ significantly. The crude fibre content of rice varieties ranged between 0.11 to 0.19 per cent in raw samples. The highest fibre content was observed in MO–95–1 (0.29%) and the lowest in variety OM–4 (0.19%). Statistical analysis of data revealed that parboiling significantly influenced the crude fibre content of rice varieties. The fibre content of the parboiled, samples ranged, between 0.23 to 0.44 per cent. In parboiled rice, the highest fibre content was observed in MO – 95 – 1 (0.44%) and lowest in OM – 4 (0.23%).

The data revealed that the interaction between the varieties and processing method was also found to be significant with respect to fibre content (F = 4.24**).

A significant difference among the varieties was noticed with respect to total ash content. The highest value of total ash content was recorded in the variety MO8-20–KR (0.93%) and the lowest in MO–95–1 (0.35%). The mean value obtained for raw rice was 0.42 per cent and that of parboiled rice was 0.58 per cent. The interaction between the varieties and processing method was also found to be significant (F = 4.96**).

Calcium, phosphorus and Iron content of the rice varieties were estimated and are depicted in Table 13.

The statistical analysis of the data revealed that there exists a significant difference in calcium content among the rice varieties. Highest value for calcium

Table: 12 Crude fibre and Total mineral content of rice varieties

Variety	Crude fibre (%)			Total mineral (%)		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	0.19	0.33	0.26	0.37	0.63	0.50
MO6-10-KR	0.18	0.39	0.28	0.47	0.47	0.47
MO8-20-KR	0.17	0.27	0.22	0.70	1.17	0.93
MO-87-5	0.19	0.24	0.22	0.33	0.63	0.48
MO-95-1	0.15	0.44	0.29	0.33	0.37	0.35
OM-2	0.19	0.31	0.25	0.40	0.43	0.42
OM-3	0.11	0.41	0.26	0.33	0.57	0.45
OM-4	0.15	0.23	0.19	0.43	0.33	0.38
Mean	**0.17**	**0.33**		**0.42**	**0.58**	

	CD values	F values	CD values	F values
Varieties	6.597	2.44 *	0.124	18.22 **
Treatments	3.299	101.93 **	6.188	25.83 **
VxT	9.329	4.24 **	0.175	4.96 **

** Significant at 1% level

* Significant at 5% level

content was observed in MO8–20–KR (12 mg). Lowest value for calcium content was noted in OM–3 (10.18 mg). Calcium content in raw rice ranged between 9.17 to 11.33 mg.

Parboiling significantly increased the calcium content in the rice varieties. Mean value recorded for parboiled rice was 12.31 mg and that of raw rice was 9.95 mg. The calcium content in parboiled rice ranged between 11.20 to 13.50 mg. The highest calcium content after parboiling was noticed in OM– 4 (13.50 mg) and the lowest value in OM–3 (11.20 mg). The interaction between the varieties and processing method was also found to be significant with respect to calcium content (F = 25.93**).

In the present study, the phosphorus content of raw rice ranged between 112.33 to 127.20 mg, while that of parboiled rice it was between 130.83 to 149.00 mg. A significant difference was observed in phosphorus content with variations. Highest phosphorous content was observed in variety MO8–20–KR (138.10 mg) and lowest in variety OM-2 (124.17mg). Statistical analysis of the data revealed that due to parboiling, there was a significant increase in phosphorous content of rice varieties when compared to raw rice. The mean value noted for parboiled rice was 137.94 mg and that of raw rice was 120.32 mg. The interaction between the varieties and processing method was also found to be significant (F = 71.99**).

There was a significant difference in iron content of the rice varieties. Highest value of iron content was noticed in MO8-20-KR (2.02mg), and lowest in OM – 3 (1.07 mg). Iron content of raw rice ranged between 0.63 to 2.03 mg and that of parboiled rice, it ranged between 1.50 to 2.30 mg.

Statistical analysis revealed that there was significant difference in the iron content among the rice varieties with respect to processing method. Mean value of iron in raw rice was found to be 1.09 mg, while that of parboiled rice was 1.92 mg.

Table: 13 Calcium, Phosphorus and Iron content of rice varieties

Variety	Calcium (mg/100g)			Phosphorus (mg/100g)			Iron (mg/100g)		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	10.33	12.17	11.25	119.33	147.23	133.28	0.90	2.10	1.50
MO6-10-KR	10.60	11.33	10.97	123.37	134.17	128.27	1.00	2.03	1.52
MO8-20-KR	11.33	12.67	12.00	127.20	149.00	138.10	2.03	2.00	2.02
MO-87-5	9.27	12.10	10.68	123.83	131.77	127.80	1.23	2.30	1.77
MO-95-1	9.17	13.27	11.22	120.27	130.83	125.55	0.93	1.60	1.27
OM-2	10.43	12.27	11.35	117.17	131.17	124.17	1.13	1.87	1.50
OM-3	9.17	11.20	10.18	112.33	137.17	124.75	0.63	1.50	1.07
OM-4	9.27	13.50	11.38	120.07	142.17	131.12	0.87	1.93	1.40
Mean	**9.95**	**12.31**		**120.32**	**137.94**		**1.09**	**1.92**	

	Calcium CD values	Calcium F values	Phosphorus CD values	Phosphorus F values	Iron CD values	Iron F values
Varieties	0.357	18.79 **	1.262	120.02 **	1.038	50.61**
Treatments	0.179	731.48 **	0.631	3242.72 **	5.189	816.81 **
VxT	0.505	25.93 **	1.785	71.99 **	1.468	22.99 **

*Significant at 1% level

There was slight increase in iron content of rice varieties due to processing. The result also revealed that significant interaction was noticed between varieties and processing method applied (F = 22.99**).

The values of thiamine content of the rice varieties are depicted in Table 14.

Table: 14 Thiamine content of rice varieties

Variety	Thiamine (mg/100g)		
	Raw rice	Parboiled rice	Mean
M-108-262-1	0.07	0.19	0.13
MO6-10-KR	0.11	0.29	0.20
MO8-20-KR	0.09	0.03	0.06
MO-87-5	0.03	0.21	0.12
MO-95-1	0.23	0.34	0.29
OM-2	0.06	0.04	0.05
OM-3	0.03	0.13	0.08
OM-4	0.11	0.10	0.11
Mean	**0.09**	**0.17**	

	CD values	F values
Varieties	0.011	466.24 **
Treatments	5.308	830.78 **
VxT	1.501	164.05 **

** Significant at 1% level

It was observed that there was significant difference among the varieties in terms of thiamine content. The thiamine content of rice varieties ranged between 0.03 to 0.23 mg in raw rice samples. The highest thiamine content was observed in MO–95–1 (0.29mg) and the lowest in variety OM–2 (0.05 mg). Statistical analysis of data revealed that parboiling significantly influenced the thiamine content of rice varieties. The thiamine content of parboiled samples ranged between 0.03 to 0.34

mg. The mean value obtained for raw rice was 0.09 mg and that of parboiled rice it was 0.17 mg. The interaction between the varieties and processing method was also found to be significant with respect to thiamine content (F = 164.05**).

4.4 Organoleptic qualities

The consumer demand for rice quality involves appearance of rice as grain and the eating quality. Rice appearance includes grain size, shape and chalkiness. Eating quality includes: appearance, flavour, taste, hardness, stickiness and over all acceptability of cooked rice (Chen and Chu, 2001).

Sensory evaluation is a science which uses the human senses to measure the texture, appearance, aroma and flavour of food products. The qualities can be measured objectively using proper instrumentation and subjectively using a sensory panel.

Quality attributes selected in this study were colour, appearance, flavour, taste and doneness. The attributes such as appearance, tenderness and flavour of cooked rice are the final criteria of cooking quality and determines the palatability of eating characteristic of cooked rice.

The scores obtained for the quality attributes, 'colour' and 'appearance' of the eight rice varieties are presented in Table 15.

Colour, one of the important visual attribute has been used to judge the overall quality of food for a very long time. In the present study, among the eight rice varieties MO-87-5 had obtained highest score (3.10) for colour while the variety MO6-10-KR obtained the lowest score (2.60).

The colour preference was found to be affected by parboiling process. In the present study, preferences were shown for the colour of parboiled rice samples, when

Table: 15 Colour and Appearance of rice varieties (Mean scores)

Variety	Colour			Appearance		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	3.20	2.80	3.00	2.70	2.70	2.70
MO6-10-KR	2.50	2.70	2.60	2.50	2.90	2.70
MO8-20-KR	2.50	3.50	3.00	2.40	3.30	2.85
MO-87-5	3.00	3.20	3.10	2.80	2.80	2.80
MO-95-1	2.80	3.10	2.95	2.70	2.90	2.80
OM-2	3.10	3.00	3.05	2.50	3.00	2.75
OM-3	3.10	3.00	3.05	2.80	3.30	3.05
OM-4	3.10	3.00	3.05	2.90	3.10	3.00
Mean	**2.91**	**3.03**		**2.66**	**3.00**	

	Colour CD values	Colour F values	Appearance CD values	Appearance F values
Varieties	0.356	1.51	0.394	0.84
Treatments	0.178	1.89	0.197	11.25 **
VxT	0.503	2.66*	0.557	1.12

** Significant at 1% level

* Significant at 5% level

compared to raw rice samples. Mean score obtained for colour of raw rice varieties was 2.91 and that of parboiled rice varieties was 3.03.

Statistical analysis revealed that significant interaction was also noticed between variety and treatments with respect to attribute colour (F = 2.66*).

A significant difference was observed in the mean scores obtained for different treatments of rice for the attribute appearance (Table 15). Among the eight rice varieties selected, OM-3 had obtained the highest score for appearance (3.05), while varieties such as M-108-262-1 and M06-10-KR had obtained the lowest score (2.70). There was not much significant difference in the mean scores obtained for each variety for the quality attributes 'appearance' when processed by raw and parboiling methods. Mean score for raw rice was 2.66, while that of parboiled rice was recorded as 3.00. The interaction between the varieties and treatments was found not be significant with respect to attribute 'appearance'.

The values of flavour and doneness of rice varieties are presented in Table 16.

There was not much significant difference among the different rice varieties for the quality attribute 'flavour' as shown in Table 16. Among the eight rice varieties the highest score for flavour was obtained for M08-20-KR (2.95) and the lowest score for the varieties such as OM-2 and OM-4 (2.55).

The flavour of the different rice varieties did not have a significant influence on parboiling method. The mean score obtained for flavour of raw rice varieties was 2.78 while that of parboiled rice varieties was 2.75. The interaction between varieties and treatments was also not significant with respect to 'flavour' (F = 1.34).

The doneness of the rice varieties was also found to be highest for the varieties M-108-262-1, M06-10-KR and MO-87-5 (3.55), which was found to be on

Table: 16 Flavour and Doneness of rice varieties (Mean scores)

Variety	Flavour			Doneness		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	2.90	2.90	2.90	3.40	3.70	3.55
MO6-10-KR	2.80	2.90	2.85	3.40	3.70	3.55
MO8-20-KR	2.70	3.20	2.95	3.30	3.70	3.50
MO-87-5	2.90	2.90	2.90	3.50	3.60	3.55
MO-95-1	2.80	2.80	2.80	3.30	3.50	3.40
OM-2	2.80	2.30	2.55	3.30	3.10	3.20
OM-3	2.80	2.50	2.65	2.80	3.60	3.20
OM-4	2.60	2.50	2.55	3.30	3.60	3.45
Mean	**2.78**	**2.75**		**3.28**	**3.56**	

	Flavour CD values	Flavour F values	Doneness CD values	Doneness F values
Varieties	0.349	1.66	0.438	0.88
Treatments	0.174	0.17	0.219	6.03*
VxT	0.493	1.34	0.620	0.79

* Significant at 5% level

par with variety M08-20-KR (3.50). Doneness was found to be lowest in varieties OM-2 and OM-3 (3.20). There was no significant difference among the different rice varieties with respect to quality attribute 'doneness'.

Statistical data revealed that there was significant difference among the eight rice varieties with respect to quality attribute doneness due to parboiling process. Mean scores obtained for doneness of the raw cooked rice was 3.28, while that of parboiled cooked rice was 3.56.

Details of quality attributes 'taste' and over all acceptability is depicted in Table 17.

Among the various quality attributes, taste is the primary one and of utmost important. There was no significant difference among the rice varieties for taste attribute. Among the eight rice varieties, highest score for taste was obtained for MO8-20-KR and MO-87-5 (3.00) and lowest for variety MO-95-1 (2.55).

Significant difference was observed with respect to the quality attribute 'taste' in the eight rice varieties due to parboiling process. In raw rice, mean score obtained for the quality attribute taste was 2.75 and that of parboiled cooked rice was 2.93

The overall acceptability of different rice varieties was not significantly different. Variety M08-20-KR was found to be most acceptable rice with a maximum score of 23.30, followed by variety MO-87-5 (23.25). The minimum score was obtained for variety OM-2 (22.20). There was significant difference between the raw and parboiled rice varieties with respect to over all acceptability (F = 9.96**).

4.5 Selection of superior variety

The superior variety was selected based on cooking, nutritional and organoleptic qualities of rice varieties (Table.18)

Table: 17 Taste and Over all acceptability of rice varieties (Mean scores)

Variety	Taste			Overall acceptability		
	Raw rice	Parboiled rice	Mean	Raw rice	Parboiled rice	Mean
M-108-262-1	2.90	3.00	2.95	22.90	23.30	23.10
MO6-10-KR	2.80	3.00	2.90	22.50	23.50	23.00
MO8-20-KR	2.70	3.30	3.00	22.10	24.50	23.30
MO-87-5	3.10	2.90	3.00	23.30	23.20	23.25
MO-95-1	2.60	2.50	2.55	22.40	22.70	22.55
OM-2	2.70	2.70	2.70	22.30	22.10	22.20
OM-3	2.50	3.10	2.80	21.90	23.50	22.70
OM-4	2.70	3.00	2.85	22.50	23.20	22.85
Mean	**2.75**	**2.93**		**22.49**	**23.25**	

	Taste CD values	Taste F values	Overall acceptability CD values	Overall acceptability F values
Varieties	0.322	1.81	0.947	1.19
Treatments	0.161	5.17 *	0.473	9.96**
VxT	0.456	1.65	1.339	1.67

** Significant at 1% level

* Significant at 5% level

Variety MO8-20-KR was found to be the superior variety of rice in both raw (1335.94) and in parboiled (1775.78) forms, followed by variety MO-87-5 having scored 1286.11 in raw form and 1772.29 in parboiled form. The varieties MO-95-1 and MO6-10-KR assumed the next two ranks in both forms, with variation among them selves. The varieties, OM-4 and OM-2 occupied seventh and eighth position in both the cases.

Table: 18 Selection of superior variety based on cooking, nutritional and organoleptic qualities

Variety	Index Score	
	Raw rice	Parboiled rice
M-108-262-1	1248.05 (6)	1727.31 (5)
MO6-10-KR	1264.11 (4)	1755.42 (4)
MO8-20-KR	1335.94 (1)	1775.78 (1)
MO-87-5	1286.11 (2)	1772.29 (3)
MO-95-1	1271.84 (3)	1773.29 (2)
OM-2	1235.79 (8)	1691.06 (8)
OM-3	1250.34 (5)	1720.64 (6)
OM-4	1240.97 (7)	1720.25 (7)

(Figures in parenthesis indicate rank order)

DISCUSSION

5. DISCUSSION

This chapter encompasses a critical appraisal of the salient findings of the study "Quality analysis of pre-release rice cultures of KAU" and the discussion is presented under

5.1 Physical characteristics

5.2 Cooking Characteristics

5.3 Nutritional Composition and

5.4 Organoleptic qualities

5.5 Selection of superior variety

5.1. Physical characteristics

Rice quality depends on a combination of several physicochemical properties of the rice grains. Depending a dietary habit and cooking method, the definition of quality varies from region to region in the world (Malik and Chaudhary, 2001).

Rice is produced and marketed according to grain size and shape. Therefore physical dimensions such as weight and uniformity of kernels is of prime importance. Grain type categories are based upon three physical qualities: length, width and weight. In the present study all the eight rice varieties studied are classified into bold medium grain rice category.

Preference for grain size and shape vary from one group of consumers to the other. Some ethnic groups prefer short bold grains, some for medium long grains and others long slender grains. In general long grains are preferred in Indian Subcontinent. (Dela and Khush, 2000)

When colour was observed among eight varieties, it was found to be white. Rice is very sensitive for colour change. Parboiling depending on the processing conditions, alter the color of rice to varying extent. In the present study, parboiling process was found to change the colour of all varieties. Varadharaju et al. (2001) reported that if the temperature is at 140^{0}C it would influence the change of colour in optimum parboiled samples.

The grain size and shape of rice are important characteristics, which determine the consumer preference as well as the commercial success of a variety. These greatly affect the head rice recovery and the milling quality (Veni and Rani, 2008).

Physical dimensions like length, breadth or width and thickness of the kernels vary according to the variety and are considered as most important criteria of rice quality in developing new varieties.

In the present study, the length was found to be highest for the variety M 08-20-KR (6.88mm) and lowest for the variety MO-87-5 (5.60 mm). There was slight but apparent change in the length of milled rice due to escape of moisture during parboiling. This result confirms with the earlier observation on parboiled rice by Korde et al. (2006).

Sadhna et al. (1998) reported significant difference between raw and parboiled rice with respect to grain length and L/B ratio. The authors also stated that long grain rice had greater length and L/B ratio, while grain weight was higher for others. Also, hand pounded rice had significantly higher grain length, grain weight and L/B ratio, while density and bulk density values were higher in machine milled rice .

Grain width is important factor in determining grain shape and weight (Badawi and EI- Hissewy, 2001).

In the present study, the width was found to be highest for the variety OM-3 and lowest for variety MO-95-1 It was found that the width of the rice varieties decreased due to parboiling treatment. This may be due to rounding of the peripheral contour and disappearance of the lateral ridges along the short axes during parboiling which makes the grain look roundish as compared to raw rice. Similar results were also observed by Korde et al. (2006).

The L/B ratio varied between the rice varieties. In the present study, it was found that there was not much difference between the L/B ratio of eight rice varieties with respect to processing method. A slight increase in L/B ratio of parboiled rice was observed when compared to raw rice, which may be due to the variation in the grain dimensions and shape of the varieties selected. This result is on tune with findings of Chaudhary et al. (2007).

In the present study the L/B ratio ranged between 2.16 to 2.91. Dela and Khush (2000) opined that the length breadth ratio (L/B) falling between 2.50 and 3.00 is acceptable, when the length is more than 6mm.

Thousand grain weight is considered to be a function of kernel size and its density and this determines milling quality. Thousand grain weights is a major determinant in adjusting the popularity of rice varieties. Farmers prefer grains with higher thousand grain weight.

In the present study, values for thousand grain weight were recorded highest for the variety M-108-262-1 (23.34g) for raw rice and lowest being observed in MO-95-1 (16.63g) (Fig.1) when compared with the values of popular variety Jyothi (23.50g for raw rice and 24.60 for parboiled rice, Nandini,1995). In case of parboiled

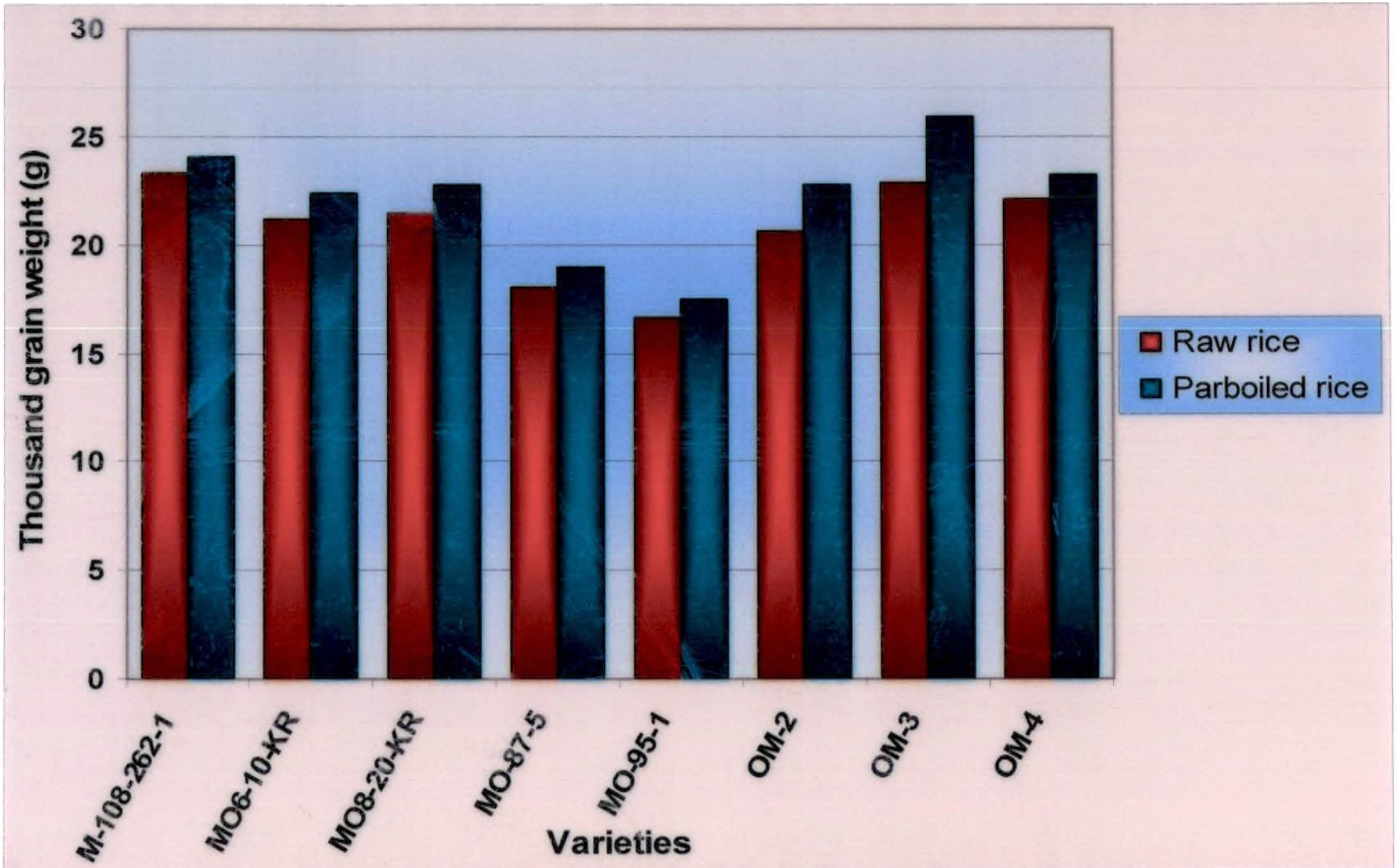

Figure.1: Effect of parboiling on thousand grain weight of rice cultures

rice varieties, highest value was recorded in variety OM-3 (25.90g) and lowest in MO-95-1 (17.50g). The thousand grain weight was found to increase after parboiling. Parboiled samples had higher thousand grain weight compared to raw samples. The increase in thousand grain weight after parboiling might be due to the excess moisture content absorbed during the process.

Yadav (2007) reported that the thousand grain weight of the rice varieties varied considerably with the moisture content in the grain. Varietal variation in thousand grain weight may occur due to variation in the shape and structure of the grains and climatic conditions at the time of harvest.

Swelling capacity is the ratio of the final to the initial volume or weight of the rice. In the present study, it was observed that swelling capacity /seed was more for parboiled rice (0.017 ml/seed) when compared to raw rice (0.010 ml /seed). Swelling capacity increased after parboiling process. The result is in confirmation with study conducted by Korde et al. (2006).

Begum and Bhattacharya (2000) reported that the nature and amount of non starch constituents are important factors which act as physical barriers to the swelling of starch granules due to lower water uptake by rice kernel on cooking. The authors also stated that the difference in surface area of the kernel among the varieties would also influence water absorption during cooking.

In the present study, the swelling index of rice varieties was more for parboiled rice when compared to raw rice. Swelling index was found to be ranged between 0.10 to 0.51 in raw rice samples and 0.33 to 0.90 in parboiled rice samples. This result confirms with the earlier observation by Bhavani (2002).

5.2. Cooking characteristics

Cooking and processing qualities largely determined the economic value of rice. These are assessed by determining optimum cooking time, volume expansion, elongation ratio, water uptake, gruel loss, cooked weight, gelatinization temperature, amylose, amylopectin and amylose – amylopectin ratio.

Cooking time is important as it determines tenderness of cooked rice as well as stickiness to a great extent (Anon, 1997). Cooking time is one of the major determinants of the quality of rice grain. Consumers prefer rice grain with less cooking time. In the present study, optimum cooking time varied significantly vary among the rice varieties. The variety MO-87-5 took higher cooking time (48.16 min) and variety OM-2 took lesser time to cook (32.33 min). Parboiling process significantly increased the cooking time of rice varieties (Fig.2). The increase in the optimum cooking time after parboiling may be due to the variation in the rate of hydration and consequent gelatinization. Korde et al. (2006) have reported similar observations.

Limpawattana et al. (2008) reported that cooking time varied between 38-45 min depending on the rice types.

According to Usha et al. (1999) discoloured rice requires significantly less time to cook. The author also reported that pre soaking causes a reduction in cooking time. Begum and Bhattacharya (2000) found that when more fat was available in raw rice, cooking time increases. Reverse phenomenon observed in glutinous varieties, which consume more time as against low fat content.

Volume expansion or kernel expansion is determined from the ratio between the cooked volumes of rice to that of uncooked rice. Higher volume expansion after cooking is a desirable trait preferred by consumers.

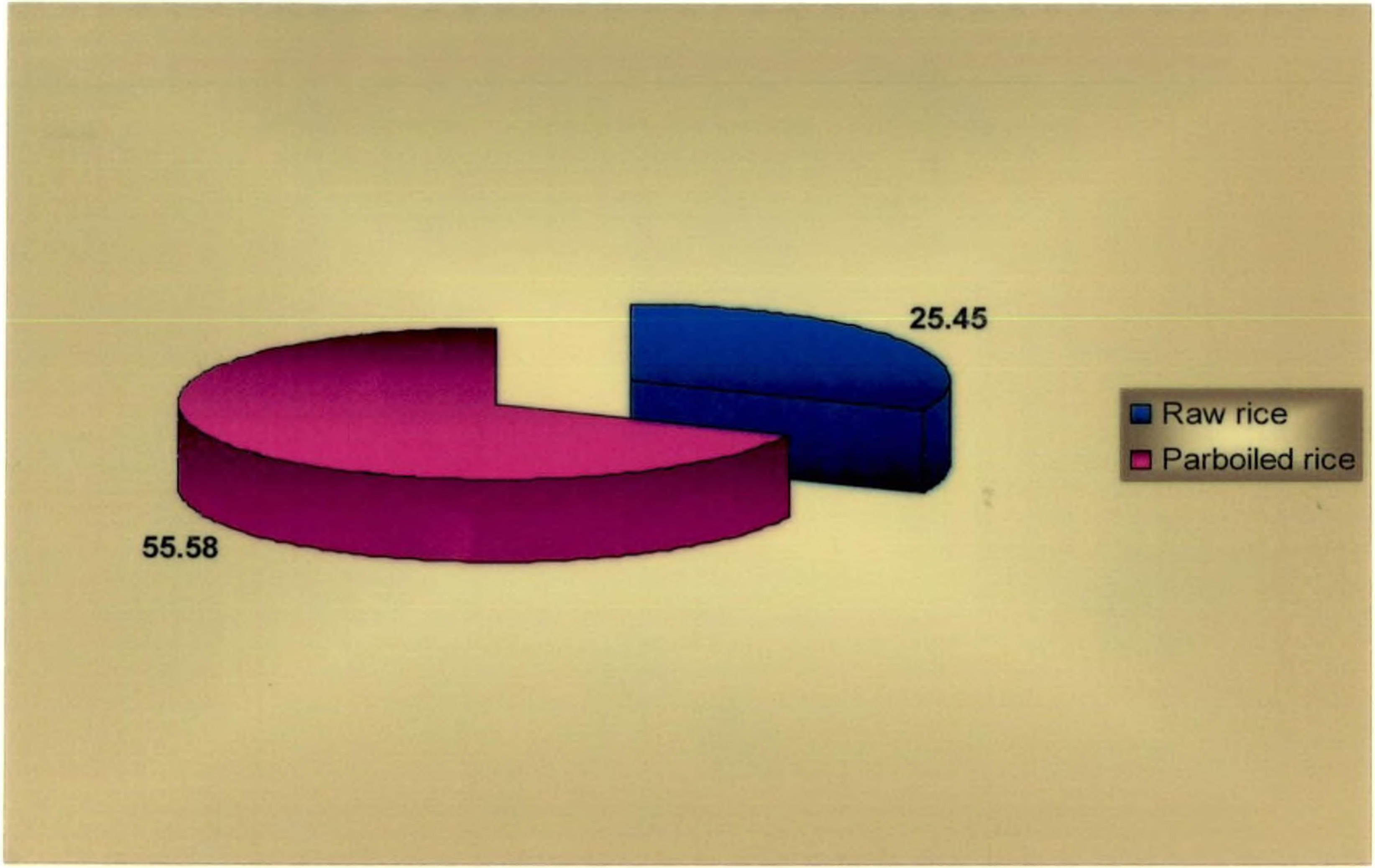

Figure.2: Cooking time of raw and parboiled rice (mean value)

A significant decrease in volume expansion was observed when rice varieties were parboiled. Volume expansion of raw rice was noted to be high (5.32), compared to parboiled rice (4.95). In raw rice, volume expansion was highest in variety MO-95-1 (5.90), and in parboiled rice, variety MO8-20-KR (5.33). When compared with popular variety Jyothi, it was found to be 5.45 for raw rice and 5.40 for parboiled rice. This can be explained from the finding of Kumari and Padmavathi (1991) who found that volume expansion was less for short grain varieties than long grain varieties and parboiling process decreased the length of the varieties. But in some varieties viz., OM-2 and OM-3 volume expansion was increased after parboiling. This may be due to loosened husk and other factors related to changes brought about during the parboiling operations. This finding is on line with the study of Tang (2002).

Das et al. (2005) reported that volume expansion was found to be decreased significantly in the case of parboiled rice samples when compared to raw samples. Usha et al. (1999) stated that discolored rice reduces kernel elongation in cooked rice.

For cooked rice grain quality, greater length elongation, less gruel loss and maximum volume expansion, and less water absorption have been associated with high quality rice varieties (Tang, 2002).

Elongation ratio is the ratio between the length of cooked grain and that of the raw grain. Higher values for elongation ratio of cooked rice are a positive and desirable character.

A significant varietal variation was observed in the elongation ratio of different rice varieties. In the present study, it was noticed that parboiling significantly increased the elongation ratio as noted to be 1.63 in parboiled samples and 1.52 in raw rice samples (Fig.3). The highest elongation ratio was possessed by MO6-10-KR in both raw and parboiled rice; the value obtained was 1.62 and 1.75

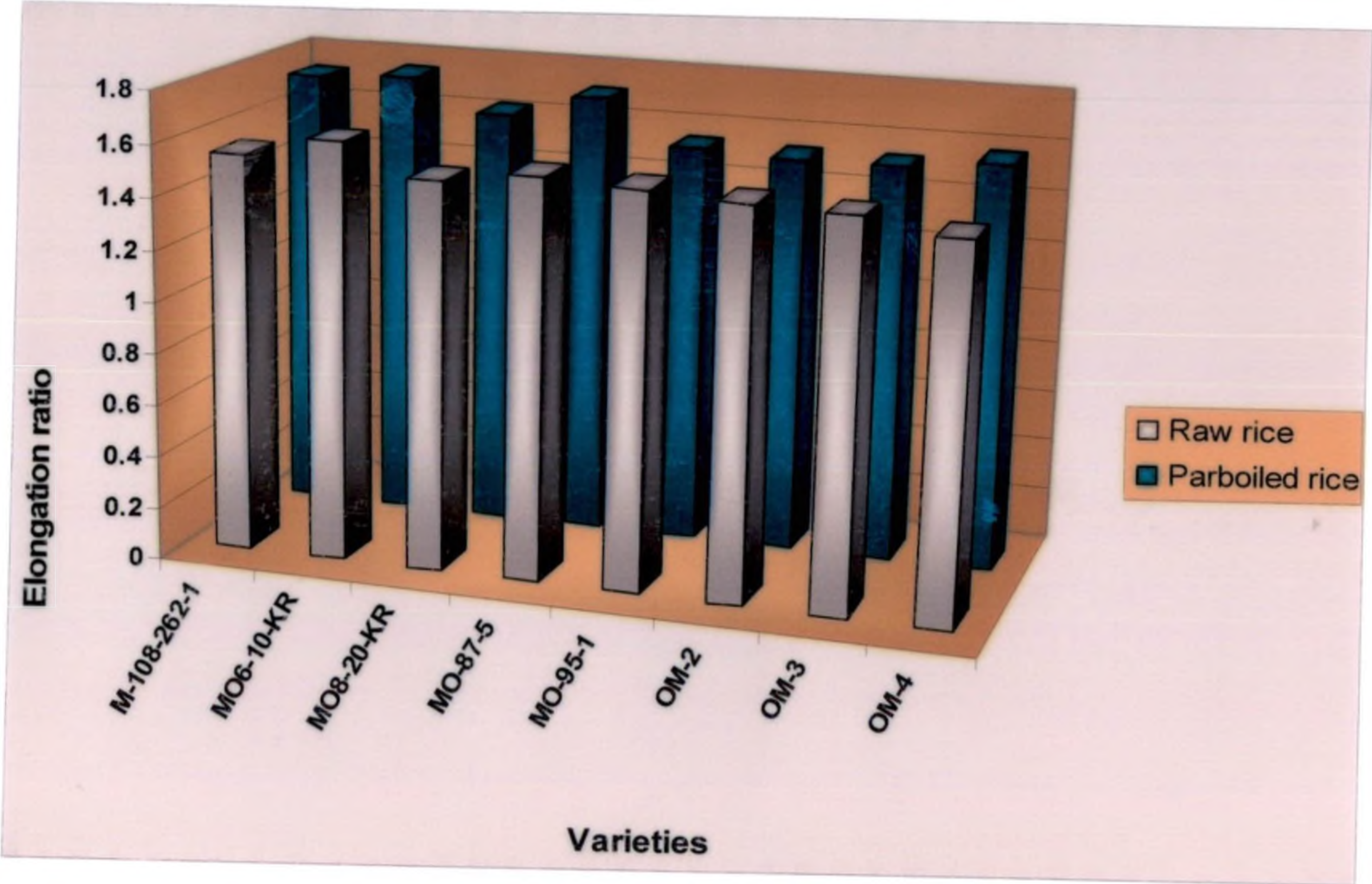

Figure.3: Elongation ratio of rice cultures

respectively. The elongation ratio was found to be higher when compared with popular variety Jyothi, and the values obtained for raw rice was 1.50 and 1.63 for parboiled rice. The increase in elongation ratio might be due to increased grain length brought about by parboiling of paddy. This result is in line with findings of Kaur et al. (1991) and Dipti et al. (2002).

Kernel elongation ratio is a quantitative trait of lengthwise expansion without increase in girth and is considered highly desirable trait in basmati rice (Rayaguru and Pandey, 2008).

Water uptake is another important index of cooking quality of rice. Higher water uptake is an indicator of better cooking quality of rice. Begum and Bhattacharya (2000) reported that when more fat was available in raw rice, water uptake decreases.

In the present study compared to raw rice varieties, parboiled had a significantly higher value for water uptake ratio. The mean value obtained for raw rice was 1.33 and that of parboiled rice was 1.57. This was explained as parboiling changes the absorptive capacity of rice and radically alters the hydration characteristics. Parboiled rice samples were found to absorb higher amount of water during cooking. Similar results were also reported by Neelofer (1992) and Otebaya et al. (2001).

The loss of carbohydrates principally starch and non-starch polysaccharides and lipids through the gruel is termed as gruel loss. Gruel loss is an important cooking characteristic of rice. Higher the gruel loss, greater will be the nutrient loss. So the variety which has lower gruel loss is nutritionally superior.

In the present study, gruel loss was more experienced from raw rice (4.90%) when compared to parboiled rice (1.83%). In raw rice, the more gruel loss was obtained in variety MO6-10-KR (8.49 %) and in parboiled rice, variety M-108-262-1 (4.69 %) was obtained more gruel loss. A comparison with popular variety Jyothi, it was found to be higher and the values obtained for raw rice was 3.25 per cent and 2.00 per cent for parboiled rice. The parboiling process decreases the gruel loss mainly because starch in parboiled rice is already cooked or gelatinized. This study confirms with the findings of Sheena (1997) and Bhavani (2002). Gruel loss was significantly affected by process of parboiling. Results focused that gruel loss has been significantly decreased in parboiling. The mean gruel loss in raw and parboiled samples was 4.90 and 1.83 per cent respectively.

In the present study, a significant difference in cooked weight was observed among rice varieties. Parboiling process significantly decreased the cooked weight of the rice varieties. The mean cooked weight for parboiled rice was 50.45g and that of raw rice was 66.93g. The interaction between the rice varieties and processing methods was also found to be significant.

Gelatinization temperature is the temperature at which rice starch begins to melt (gelatinize) and take up water. Gelatinization temperature strongly influences the cooking quality of rice.

The gelatinization ability of starches is influenced by many parameters such as the amylose, amylopection ratio, the degree of hydration and the size of starch granule (Oghbaei and Prakash, 2010).

In the present study, parboiled rice when compared to raw rice had a significantly higher value for gelatinization temperature. The mean value obtained for raw rice was 64.33^{0}C and that for parboiled rice was 67.29^{0}C. In parboiling process, starch gelatinizes in the grain to ensure discrete rice kernels when cooked. The gelatinization temperature was found to increase with parboiling process. This may be because gelatinization temperature is negatively influenced by the total amylose content. Similar results were reported by Yadav (2007).

According to Dela and Khush (2000) gelatinization temperature of rice ranged from 55 to 79^0C. Singh et al. (2000) reported that rice varieties with intermediate gelatinization temperature (70-74^0C) are preferred all over the world, as at high gelatinization temperature rice remains mainly under cooked, under standard cooking procedure and hence least preferred.

Amylose is a linear fraction of starch and has negative influence on taste panel scores of tenderness, cohesiveness and gloss of cooked rice. If the amylose content is absent, as in waxy (glutinous) rice, such rice do not expand in volume, glossy and sticky and remain firm when cooked. High amylose content rice shows high volume expansion (not necessarily elongation) and a degree of flakiness. They cook dry, are less tender and become hard upon cooling. Low amylose rice cooks moist and is sticky. Intermediate amylose rice cooks moist and tender and do not become hard upon cooling. Intermediate amylose rice is the preferred types in most of the rice growing areas of the world. Amylose content can range from 15-30 per cent and can indicate the cooked texture of the rice (Ward and Martin, 2009).

In the present study, amylose content varied significantly among the rice varieties. A significant decrease in amylose content was observed after parboiling. This may be due to the loss of gluten into the gruel. Such negative effect of parboiling on amylose content was also reported by Korde et al. (2006) and Roy et al. (2009).

According to Shi et al. (2005) amylose content is important because firmness and stickiness are two properties of cooked rice that influence consumer preference.

Amylopectin is the major starch constituent and is the only starch fraction of waxy (glutinous) rice. In the present study, the amylopectin content varied significantly among the rice varieties. And a significant decrease in amylopectin content was observed after parboiling. The mean value of amylopectin content for parboiled rice was 51.08 per cent and that of raw rice was 54.90 per cent.

In the present study, it was noticed that amylose and amylopectin ratio varied significantly among the rice varieties. But no significant difference was observed between the method of processing applied. It was found that parboiling process slightly decreased the amylose– amylopectin ratio values (0.42), when compared to raw rice values (0.43). This may be due to variation in total starch and total amylose content. Similar findings were also reported by Kadan et al. (2007).

5.3. Nutritional composition

Rice is a rich source of energy and moderate source of protein. It contributes over 20 per cent of the total calorie intake of the human population (Bhattacharjee et al., 2002). Rice also provides minerals, vitamins and fibre.

According to Srilakshmi (2004) cereals are the main source of energy, contributing 70-80 per cent of the requirement.

An increase in calorific value was noticed as a result of parboiling. The mean value of rice samples after parboiling was estimated to be 379.25 Kcal while that of its raw counterparts was 366.08 Kcal (Fig. 4). During parboiling, the brown outer layers (scutellum and germ) adhere to the grain and most of the nutrients in it are driven into the interior of the grain. Similar finding were also reported by Heinemann et al. (2005).

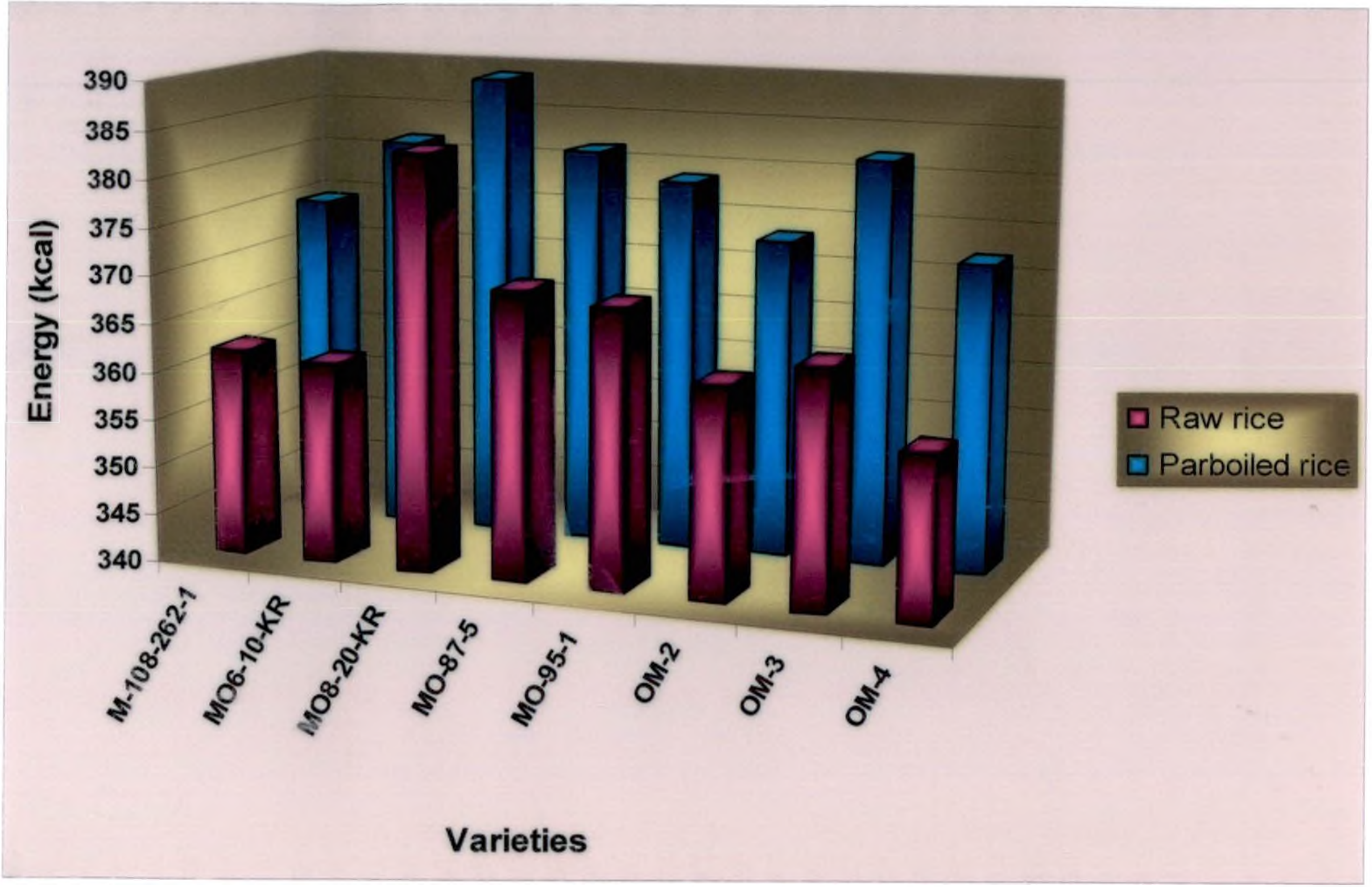

Figure. 4: Energy content of rice cultures

In the present study, the highest energy content was obtained by MO8-20-KR in both raw and parboiled rice; the values were 383.33 and 389.00 Kcal respectively. It was found to be higher when compared with popular variety Jyothi (344.70 Kcal for raw rice and 354.00 Kcal for parboiled rice) (Sreedevi, 1989).

Protein is the second most abundant constituent in rice. The protein content of rice is 7 per cent. The protein content of rice though relatively low, its nutrient value is much higher compared to other cereals. Rice protein is easily digested (up to 98 %) and contains all the essential amino acids (except lysine) which are higher in number than in other cereals crops (Zelensky, 2001).

In raw rice, the highest protein content was obtained by the variety OM-3 (7.12g/100g) and in parboiled rice, variety OM-2 (10.27g/100g). Protein content was found to be higher when compared with popular variety Jyothi (8.10g/100g for raw rice and 8.05g/100g for parboiled rice).

A Significant difference between the rice varieties was observed with respect to protein content. The highest value of protein content was noted in OM-2 (8.17 g) and lowest in OM-4 (6.24g) (Fig.5).

Okaodome et al. (1999) noticed that surface hardness was positively correlated with protein content. The surface hardness would distinguish differences in protein content among rice samples of the same cultivar.

In the present study, it was noticed that parboiling resulted in increase in the protein content and it may be due to parboiling process which forces the nutrients from the bran layer in to the centre of the grain. The resulting rice is fluffy and retains more nutrients than milled white rice. The result was in confirmation with the report of Wimberley (1983). In parboiled samples, the mean value obtained was 8.17g, while that of raw rice it was 6.42g.

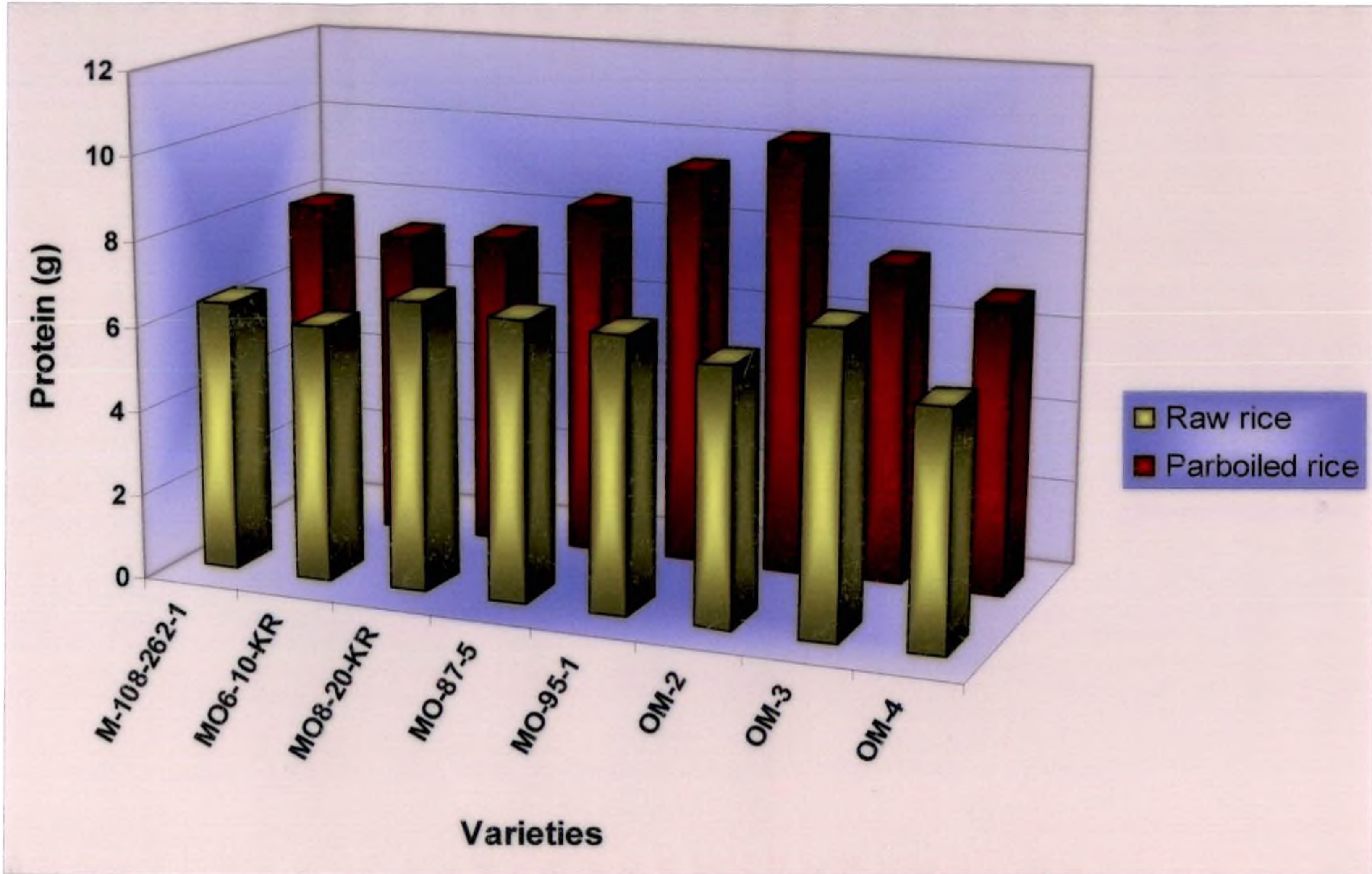

Figure. 5: Protein content of rice cultures

The study conducted by Sadhna et al. (1998) reported that parboiled rice was found to have higher protein and ash contents and lowest free amino acids and free fatty acids compared to raw rice.

Moisture content is the most important quality criterion for rice. High quality grains are those having minimum moisture, free of microbial deterioration and spoilage.

In the present study, a significant increase in moisture content was observed in parboiled rice samples (13.30 %) when compared to raw rice samples (12.59 %). This may be due to the fact that the water absorbed by starch granules during parboiling may be excess. This depends upon the amylose – amylopectin ratio of rice samples. But moisture content was found to decrease in one variety (OM-2). This may be due to significant variation in rice hardness among cultivars and this was correlated with the moisture content of rice kernel endosperm. Similar results were observed by Chen et al. (1998) and Bhashyam et al. (2002).

Fukumori and Mohri (2001) reported that during the paddy tempering state of intermittent drying, it increases the velocity of moisture transportation, if the initial differences of the moisture content of husk, brown rice and paddy temperature are high.

Starch is a polysaccharide found in nature by the condensation of a large number of glucose molecules. Starch forms 90 per cent of rice by weight. According to Srilakshmi (2004) the major carbohydrate of rice is starch which is 72-75 per cent.

In the present study, it was observed that varietal differences exist with respect to starch content of the rice varieties. The physical properties of the grain are more closely related to the starch content or to protein content than to amylose content. Also, starch content decrease with an increase in protein content.

It was noticed that starch content of rice varieties decreased as a result of parboiling. This may be due to the fact that during parboiling, starch granules gelatinized and squeezed together, making the endosperm hard and compact (Gill et al., 2003). In the present study, starch content ranged between 77.59 to 79.04 per cent in raw rice and 71.66 to 74.18 per cent in parboiled rice (Fig.6).

Crude fibre is a mixture of substances, which make up the frame work of plants and is composed of cellulose, hemicelluloses and lignin of the cell walls. Rice is a moderate source of fibre.

In the present study, it was noticed that parboiling significantly influences the fibre content. Parboiling process increase the fibre content of rice varieties. This may be due to fact that the nutrients from fibrous outer layers are forced into the centre of the grain during parboiling. Similar findings were reported by Heinemann et al. (2005). The highest fibre content was observed in MO-95-1(0.29%) and the lowest in variety OM-4(0.19%)

In the present study, it was noticed that parboiling significantly increased the total mineral content of rice varieties. The mean value obtained for raw rice was 0.42 per cent and that of parboiled rice it was 0.58 per cent. The studies conducted by Sadhna et al. (1998) reported that parboiled rice was found to have higher protein and ash contents and lowest free amino acids and free fatty acids compared to raw rice.

Parboiling resulted in an increase in the mineral content of all the rice varieties. This indicates that there is diffusion of minerals into the rice kernel during the steeping and steaming process. Raw rice had lower mineral contents than parboiled rice (Gujral and Singh, 2001). The per cent reduction in mineral content was greater with increasing degree of milling.

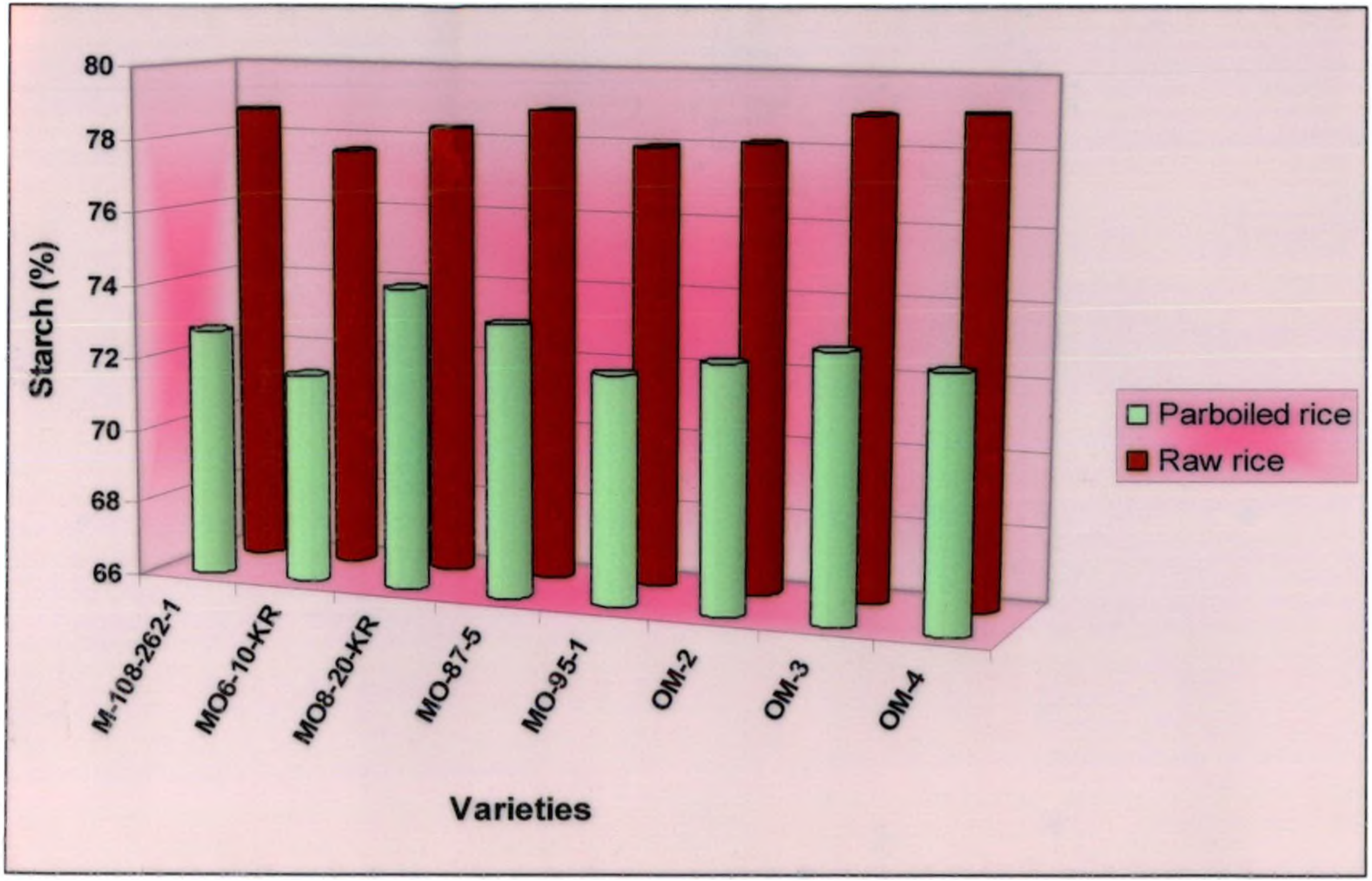

Figure. 6: Effect of parboiling on starch content of rice cultures

Rice is poor source of mineral salts particularly calcium. Generally, rice has 10 mg calcium per 100 mg and it is mostly present in bran. In the present study, a significant difference in the calcium content of rice varieties was observed among the eight varieties. It was noticed that parboiling significantly increased the calcium content of the rice varieties. Raw rice has lower content of calcium (9.95 mg/100mg) when compared to parboiled rice (12.3/mg/100mg). This may be due to nutrient elements like calcium present in outer layers migrated deep into the grain during parboiling resulting in a greater retention in milled parboiled grain. The result was in confirmation with in the report of Heinemann et al. (2005).

A study conducted by Oghbaei and Prakash (2010) they reported that the calcium content of rice samples were in the range of 13.07 to19.36mg/100g while the iron was in the range of 1.11 to 1.57mg/100g.

The phosphorous content of rice is high, about 4 per cent of which is present as phytic acid. In the present study, the highest value of phosphorous content was noticed in MO8-20-KR (138.10mg) and lowest in variety OM-2 (124.17mg). Statistical analysis of the data revealed that due to parboiling, there was a significant increase in phosphorous content of rice varieties when compared to raw rice. The mean value obtained for parboiled rice was 137.94 mg and that of raw rice was 120.32 mg

Rice is a very poor source of iron. The present study revealed that iron content of parboiled rice samples increased (1.92mg/100mg) when compared to raw rice samples (1.09mg/100mg). Highest value of iron content was noticed in MO8-20-KR (2.02mg) and lowest in OM-3(1.07mg). There was slight increase in iron content of rice varieties due to processing. This can be explained by the fact that severity of steaming in parboiling influences the minerals distribution in parboiled rice (Ocker et al., 1976). Heinemann et al. (2005) also reported that iron content was found to be retained more in parboiled rice samples when compared to raw rice samples.

Rice is a fair source of water soluble B complex vitamins. In the present study, the highest thiamine content was observed in MO-95-1(0.29mg) and the lowest in variety OM-2(0.05mg). The mean value obtained for raw rice was 0.09mg and in parboiled, it was 0.17mg. Parboiling process increases the thiamine content of rice varieties. The interaction between the varieties and processing method was found to be significant with respect to thiamine content.

Oghbaei and Prakash (2010) reported that the parboiled rice had significantly higher contents of both thiamine and riboflavin which can be attributed to the process of parboiling the grain which redistributes the water soluble vitamins in the whole kernel thus reducing the surface losses occurring due to polishing.

Study conducted by Leskova et al. (2005) reported that the fortified content for thiamine was 0.4 mg/100 mg to achieve the level of natural thiamine in rice (0.07mg/100g) to obtain approximately 0.47mg/100g. During processing, heat, light and leaching could cause losses up to 30 per cent.

Chang and Luh (1991) reported that the composition of white rice to be 0.07mg for thiamine, 0.03mg for riboflavin and 1.6mg for niacin per 100g of rice. In another study, the thiamine contents of raw milled rice varied from 0.025 to 0.045mg/100g and after parboiling, there was slight increase that is, 0.03 to 0.051mg/100g (Sotelo et al., 1990). The variation in the vitamin content of rice reported by various authors may be due to the application of fertilizer, variation in maturity period and the degree of processing (Grewal and Sangha, 2006).

5.4 Organoleptic qualities

Quality will be considered as the relative excellence of a food based on sensory estimates of colour, texture and flavour. These attributes make food desirable to consumers. Quality also encompasses wholesomeness, economy, convenience and market appearance. Food quality is evaluated by sensory, chemical and physical methods. Sensory methods are used to determine whether foods differ in such qualities as taste, odour, juiciness, tenderness or texture and the extent and direction of the differences. They are also used to determine consumer preference among food.

Sensory evaluation is defined as "A scientific discipline and to evoke, measure, analyze and interpret those responses to products that are perceived by the senses of sight, smell, touch, taste and hearing" (Stone and Sidel, 2003).

Sensory evaluation by laboratory panels and consumer panels give indication to the eating quality of rice and it varies according to personal preference.

Quality attributes selected in this study were colour, appearance, flavour, taste and doneness. The attributes such as appearance, doneness and flavour are final criteria of cooking quality and determine palatability or eating characteristics of cooked rice.

Colour, one of the important visual attribute has been used to judge the overall quality of food for a very long time. If the colour is unattractive, a potential consumer may not be impressed by any other attributes.

Colour is used as one criteria of quality of all rice varieties. The assessment is performed on whole milled rice.

Statistical analysis revealed that significant interaction exists between variety and processing method with respect to attribute colour. Parboiling process significantly affects the colour of rice varieties. In the present study, it was observed that preference for colour was higher for parboiled rice samples when compared to raw rice samples. More acceptability of parboiled rice may be due to the fact that the absorbed water during parboiling dissolves the colouring pigment in the hull and the heat applied during parboiling process drives away the pigments inwards to the endosperm, which imparts a darker colour to the grain.

The score obtained for colour of parboiled rice was 3.03 compared to raw rice 2.91. Contrary to these results, in few varieties (M-108-262-1, OM-2, OM-3, and OM-4) raw rice samples scored more.

Appearance is the criterion for the desirability of any food product. The appearance of the food product is contributed by surface characteristics viz., size, shape, colour, transparency, opaqueness, turbidity and dullness (Srilakshmi, 2004).

General appearance is an important quality trait, because mostly rice is consumed in whole grain from. Numerous factors constitute general appearance including size and shape, uniformity, translucency, chalkiness, colour, damaged and imperfect grains. In the present study, significant differences was observed in the mean scores obtained for different treatments of rice varieties with respect to quality attribute appearance. But the interaction between varieties and processing methods was not significant.

Attribute 'appearance' had gained much preference in parboiled form than in raw form. This may be because; parboiled rice retained better shape after cooking and was fluffy and less cohesive. Heinemann et al. (2005) reported that parboiled rice scored high value for appearance.

MacDougall (1998) pointed out the appearance of food products; either colour alone or in conjunction with other quality attributes influences the consumer decision at a point of sale, and colour is most important appearance attribute of food products.

Flavour is one of the important criteria for selection of superior variety. It is one of the most important sensory attributes that affects acceptability of foods (Prinyawatkul et al., 2003).

In the present study, it was revealed that there was no significant difference among rice varieties and also processing method applied, with respect to quality attribute 'flavour'. The flavour preference was found to be higher for raw rice samples. But in general, parboiled rice had a characteristic flavour compared to raw rice.

Contrary to the above result, flavour was preferred in parboiled rice for varieties such as MO6-10-KR, MO8-20-KR than in raw form.

Flavour is the blend of taste and smell perceptions noted when the food is in the mouth. The over all flavour impression is the result of the tastes perceived by the taste buds in the mouth and the aromatic compounds detected by the epithelium in the olfactory organ in the nose (Hayat et al., 2005).

Parboiling changes the doneness of the rice. Rice becomes firmer and less sticky and also, it makes it much more durable kernel. It can be over cooked without being mushy or losing its grain shape.

Lyon et al. (2000) stated that measurement of cooked rice texture attributes by sensory and instrumental methods is important because of the increasing popularity of rice and rice products by globally diverse cultures. The authors also opined that factors influencing cooked rice texture are cultivars, physico-chemical properties, post harvest handling practices (milling degree, grain conditions and final moisture) and cooking method.

The present study revealed that, there was no significant difference among the rice varieties for the quality attributes 'doneness'. The mean score obtained for raw samples was 3.28 and in parboiled samples it was 3.56. According to Juliano (1998) amylose content mainly determines the texture of cooked rice.

Amylose content can range from 15-30 per cent and can indicate the cooked texture of the rice. Low amylose content produces a soft cooking rice where high amylose usually produces a firm and fluffy rice (Ward and Martin, 2009).

Among the various quality attributes 'taste' is of primary consumer interest for its market ability. Zheng and Zhao (2000) reported that drying temperature of paddy is the main factor affecting rice taste.

In the present study, it was observed that there was no significant difference in the mean score for the quality attribute 'taste' for different varieties, but there was significant difference with respect to processing methods applied. Parboiled rice had a characteristic taste and aroma, which is mostly accepted by keralites compared with other states of India. In the present study, it was found that parboiled samples scored slightly higher values (2.93) compared to raw rice samples (2.75) similar results were also reported by Sheena (1997)

According to Savithri et al. (1990) the overall acceptability depends on the concentration of amount of particular components, the nutritional and other hidden attributes of the food and its palatability or sensory quality.

Fig.7 represents the organoleptic qualities of selected rice cultures.

In the present study, the overall acceptability of different rice varieties was not significant. But there was significant difference with respect to processing methods applied. The score obtained for over all acceptability of raw rice was 22.49 and that of parboiled was 23.25. Parboiled rice samples scored more value (Fig.8). This may be because of keralites mostly prefer parboiled rice.

5.5 Selection of superior variety

Variety MO8-20-KR was found to be the superior variety in both raw and parboiled forms, followed by varieties MO-87-5 and MO-95-1. On comparing the scores, it was observed that parboiling had favourably influenced the varieties in improving the cooking, nutritional and organoleptic qualities.

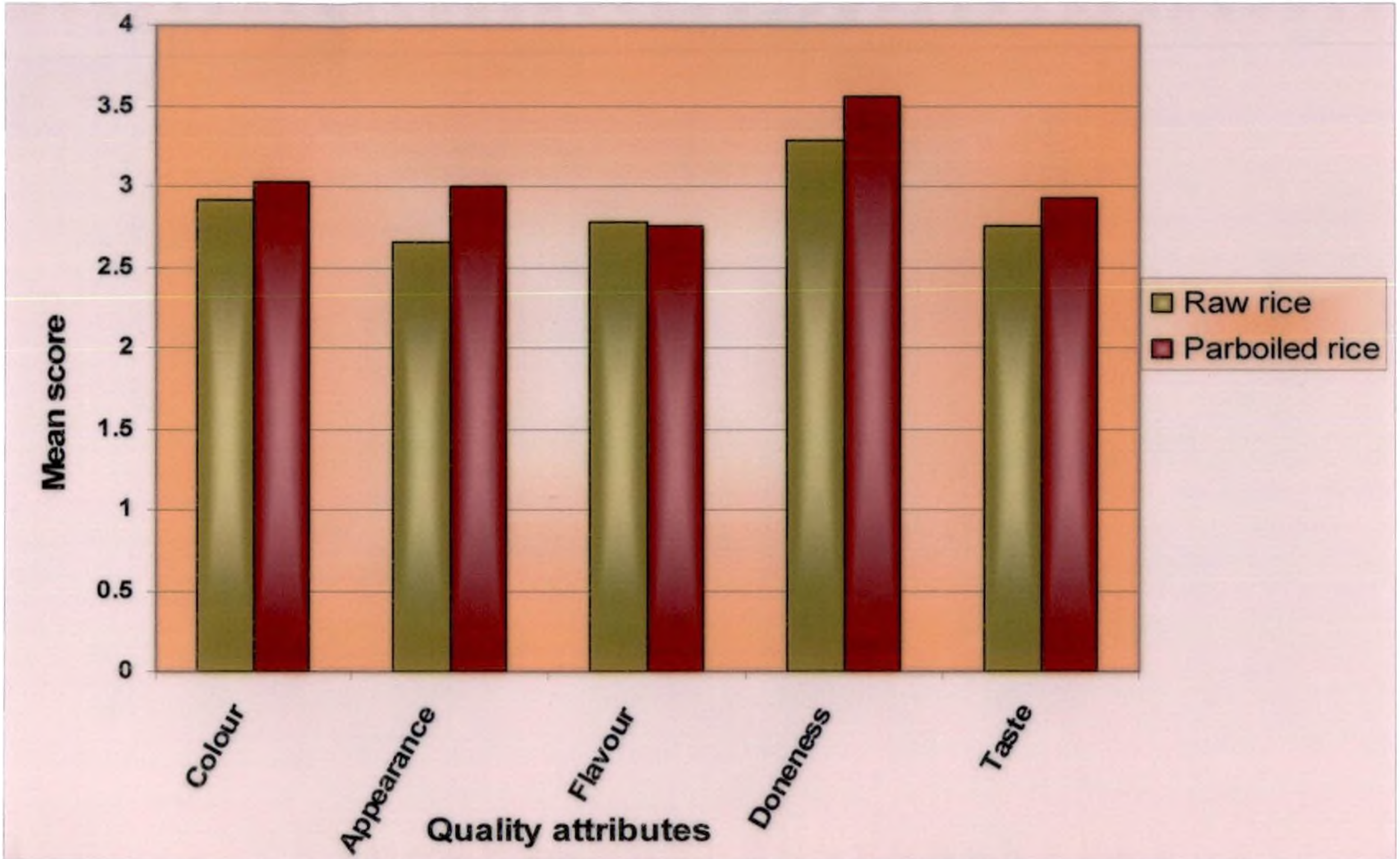

Figure. 7: Organoleptic qualities of rice cultures

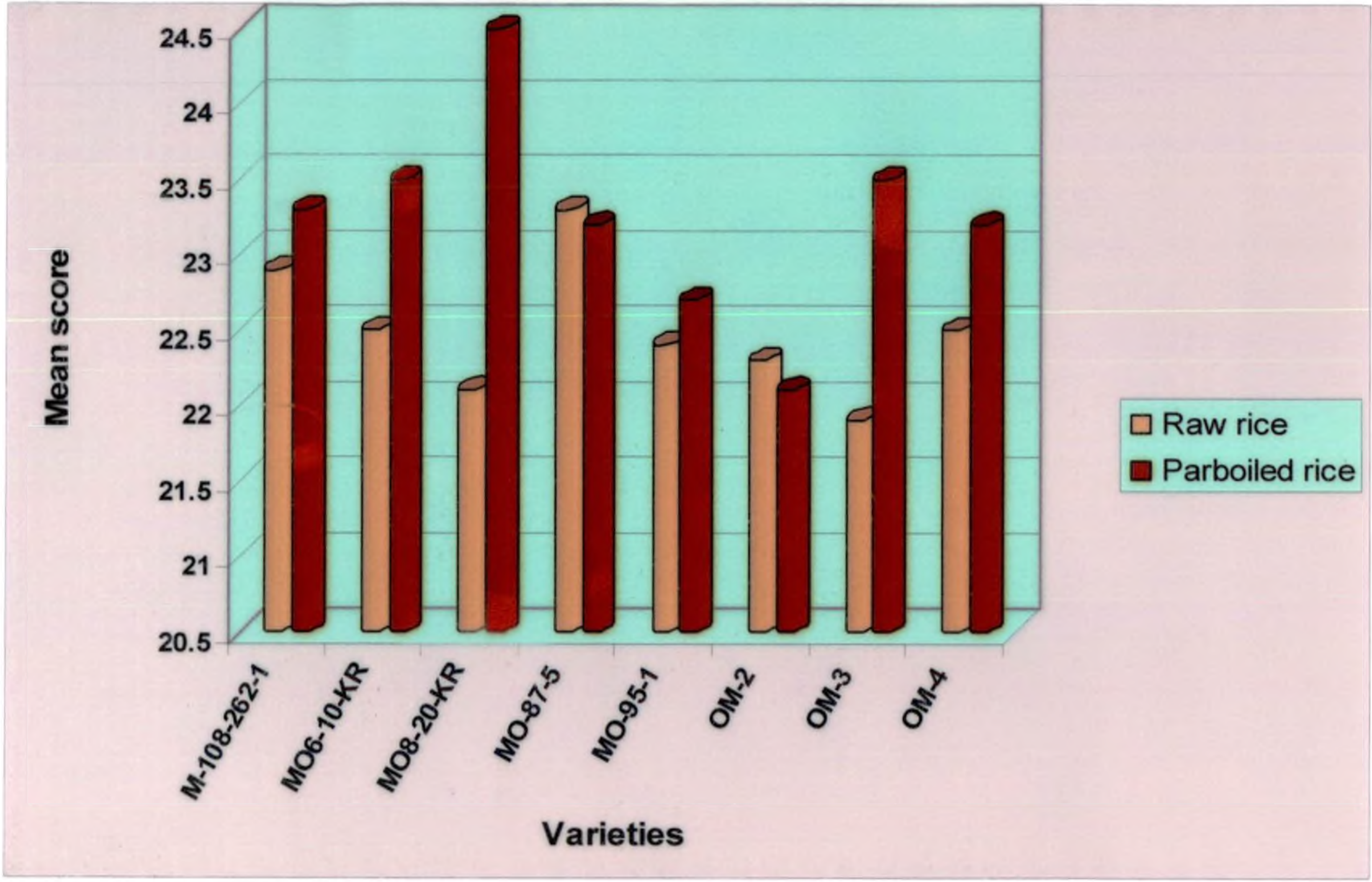

Figure. 8: Over all acceptability of rice cultures

SUMMARY

6. SUMMARY

A study entitled "Quality analysis of pre- release rice cultures of KAU" was conducted to assess the major quality parameters such as physical characteristics, cooking characteristics, nutritional composition and organoleptic characteristics. Eight rice samples were collected from Rice Research Stations (Five cultures from Moncompu and three from Kayamkulam) of Kerala Agricultural University to conduct the study and the results obtained are summarized below.

The parameters selected to study under physical characteristics were size, shape, colour, length, width, L/B ratio, thousand grain weight, hydration capacity/seed, swelling capacity/seed and swelling index.

The results revealed that all the rice varieties were found to be bold and in medium shape.

Regarding the colour of rice samples, all the varieties were found to be white in colour. There was slight change in colour of the rice varieties due to parboiling.

The length of the rice varieties was found to be the highest in MO8-20-KR and lowest in variety MO-87-5. Parboiling process was found to decrease the length and width of rice varieties and the width was found to be highest variety OM-3 and lowest in variety MO-95-1. The highest L/B ratio was recorded for the variety MO8-20- KR and lowest for the variety OM-4.

Thousand grain weight was highest for variety OM-3 and lowest for the variety MO- 95-1. Parboiled samples had significant higher thousand grain weight values compound to raw rice samples.

The highest value of hydration capacity/ seed was recorded for variety MO6-10- KR and lowest for variety MO-87- 5. Parboiled rice samples had significantly higher hydration capacity when compound to their raw counterparts.

Values for swelling capacity/ seed were found to be the highest for variety OM-4. Parboiling process significantly increased the values for swelling capacity per seed among the rice varieties

Swelling index value was found to be the highest in variety MO- 87- 5 and lowest in variety M-108-262- 1 and there was a significant increase in swelling index as a result of parboiling.

The cooking characters studied were optimum cooking time, volume expansion, elongation ratio, water uptake, gruel loss, cooked weight, gelatinization temperature, amylose, amylopectin and amylose-amylopectin ratio.

The optimum cooking time of the rice varieties was increased when the rice samples were parboiled. The variety OM-2 took lesser time to cook, while variety MO- 87-5 took maximum time to cook.

Higher volume expansion was observed in MO8-20-KR followed by MO-95-1. A significant decrease in volume expansion was observed, when rice varieties were parboiled.

Elongation index was observed to be the highest in variety MO6-10-KR. There was a significant increase in the elongation index as a result of parboiling.

Among the eight rice varieties studied, the water uptake was found to be highest for variety OM-4 and lowest in M- 108-262-1.

More gruel loss was experienced from raw rice when compared to parboiled counterparts. Nutritionally superior varieties are those which experience the least gruel loss. Variety MO-87-5 was recorded to experience the least gruel loss in the present study.

The highest value for cooked weight of rice varieties was obtained in variety MO8-20-KR and lowest in variety MO-95-1.

Highest value for gelatinization temperature was observed in variety MO8-20- KR and lowest in OM-2. A significant higher gelatinization temperature was noticed in parboiled rice samples compared to raw rice samples.

Consumers prefer rice with intermediate amylose content and in the present study; all the varieties were grouped under intermediate amylose group.

A significant decrease in amylose content was observed after parboiling. The highest amylose content was noticed in OM-4, which was on par with variety MO6-10-KR.

A significant decrease in amylopectin content was observed after parboiling. The highest amylopectin content was obtained MO8-20-KR and lowest by variety MO6-10- KR.

Amylose- amylopectin ratio varied significantly among the rice varieties. It was recorded highest in variety MO6-10-KR, which was on par with variety OM-4.

Nutritional composition of the rice varieties were assessed by estimating calorific value, protein, starch, moisture, total mineral, crude fibre, calcium, phosphorus, iron and thiamine content of the rice varieties.

Among the eight rice varieties studied MO8-20-KR was found to have the highest calorific value followed by MO-87-5. It was found that parboiling process influences the calorific value of rice varieties.

Protein content was observed to be the highest in OM-2 and it was noticed that as a result of parboiling process, there was increase in protein content of the rice varieties.

Parboiling process positively influences the moisture content of rice varieties. Highest moisture content was observed in variety MO-87-5 and MO-95-1 and lowest in variety OM-4.

Parboiling process reduced the percentage of starch in rice varieties and highest value of starch content was recorded in the variety MO8-20-KR and lowest in MO6-10- KR.

The highest fibre content was observed in MO-95-1 and the lowest in variety OM-4. Parboiling significantly influenced the crude fibre content of rice varieties.

Parboiling process positively influences the total ash content of rice varieties. The highest value of total ash content was recorded in the variety MO8- 20- KR and lowest in MO- 95- 1.

The variety MO8-20-KR was observed to have the highest value for calcium, phosphorus and iron content. Parboiling process positively influences the calcium, phosphorus and iron contents of rice varieties.

The highest thiamine content was observed in MO–95–1 and lowest in variety OM–2.

Organoleptic qualities of cooked raw and parboiled rice were scored in the present study taking into account the quality attributes like colour, appearance, flavour, doneness and taste.

Statistical analysis revealed that parboiled rice samples obtained the highest scores for the quality attributes such as colour, appearance, doneness and taste compared to their raw counterparts. Contrary to this results, quality attributes 'flavour' was scored maximum for raw rice samples. There was no significant difference between the varieties with respect to overall acceptability.

The superior variety was selected based on cooking, nutritional and organoleptic qualities of rice varieties. Variety MO8-20-KR was found to be the superior variety in both raw and in parboiled forms.

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QUALITY ANALYSIS OF PRE-RELEASE RICE CULTURES OF KAU

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ABSTRACT

"Quality analysis of pre-release rice cultures of KAU" was a study undertaken to determine the quality aspects of the pre-release rice varieties by assessing parameters like physical characteristics, cooking characteristics, nutritional composition and organoleptic qualities. The effect of parboiling on the above quality aspects was also studied.

Highest value for thousand grain weight was recorded in variety OM-3. Parboiling significantly increased the thousand grain weight, hydration capacity, swelling capacity and swelling index values.

Under, cooking characteristics, variety OM-2 took lesser time to cook. Highest value for volume expansion was observed in MO8-20-KR; for elongation ratio MO6-10-KR; for water uptake OM-4; for gruel loss M-108-262-1; for cooked weight MO8-20-KR and for gelatinization temperature MO8-20-KR. All the eight varieties studied, belonged to intermediate amylose group, MO8-20-KR and MO6-10-KR for amylopectin and amylose-amylopectin ratio respectively. Parboiling had a positive influence on most of the cooking characteristics of rice varieties.

Consumers prefer varieties of higher nutritional quality. Compared to other varieties, MO8-20-KR had obtained higher values for nutritional characteristics such as energy content, starch content, total mineral content, calcium, phosphorus and iron. Highest value of protein content was noted in OM-2. MO-87-5 and MO-95-1 were observed to record the highest values for moisture content. MO-95-1 had obtained highest values for fibre content and thiamine content. Parboiling process positively influenced the nutritional composition of the rice varieties, exceptional cases being starch.

Organoleptic evaluation of cooked rice revealed that MO8-20-KR scored the highest and therefore can be considered as the most acceptable variety with respect to the given quality attributes such as colour, appearance, flovour, doneness and taste.

To conclude, it was found that culture MO8-20-KR was considered as the best among the varieties studied, followed by culture MO-87-5.

APPENDICES

Appendix I

Specimen evaluation card for triangle test

Name: Date:

Product: Time:

Two of the three samples are identical

Determine the odd sample:

Pair number	Code number of samples	Code number of odd sample
1		
2		
3		
4		

Signature.

Appendix II

Specimen evaluation card for composite scoring test

Name: Date:

Product: Time:

Assign scores for each sample for various characteristics

Quality attributes	Maximum scores	Code number of samples							
		1	2	3	4	5	6	7	8
Colour	5								
Appearance	5								
Flavour	5								
Doneness	5								
Taste	5								

Comments:

Number of panel members selected : 10

Number of replications : 3

Signature: