QUALITY ANALYSIS OF POKKALI RICE VARIETIES / CULTURES

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DECLARATION

I hereby declare that this thesis entitled **"Quality analysis of Pokkali rice varieties / cultures"** 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 to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Quality analysis of Pokkali rice varieties / cultures"** is a record of research work done independently by Kodem Sri Bhavani 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

Cul	Culture
g	gram
mg	milligram
mm	millimetre
ml	millilitre
%	per cent
Kcal	kilo calories
KPa	kilo pascal
hrs.	hours
min.	minutes
^0C	degree Celsius
^0F	degree Fahrenheit
Ca	calcium
S	sulphur
Fig.	Figure
BIS	Bureau of Indian Standards
PER	Protein Efficiency Ratio
Ltd.	Limited

INTRODUCTION

1. INTRODUCTION

"Rice, delicious when cooked, is being worshipped as the greatest of all foods".

Rice means life in the monsoonal Asia, where approximately 90 per cent of world's rice is grown and consumed (Shobarani, 1992). In fact, India's most important contribution to world agriculture is rice, staple food of East and South East Asia (Mathews, 1991).

Rice is one of the cheapest source of food energy and protein. It contributes to 50 per cent of dietary needs and forms single most important source of calories to half the human race which depend on it in East, South East and South Asia. It supplies on an average, 1/3rd of the calories. The protein content of the rice may be low, however the quality of the protein, is superior (Saikia, 1990).

Although rice is an important staple food for majority of people, as an item of commerce, it is only of secondary importance. The world's rice production increased from 520 million tonnes in 1990 to 597 million tonnes in 2000 (FAO, 2001). In India, a total area of 44.60 million hectares was allotted to rice production. The total production in 1998 – 99 was estimated as 85.99 million tonnes giving an yield of 1930 kg / hectare (Kurup, 2000).

The many diverse uses of rice, both domestically and for export, require that quality be evaluated, according to its suitability for specific end use. Quality is based on a combination of subjective and objective factors. Quality of rice is influenced by many parameters like its physical, cooking, nutritional and organoleptic qualities. For planning a systematic breeding programme, an understanding of the quality attributes is a pre- requisite.

The *Pokkali* area lies in the coastal regions of Ernakulam and Kannur districts. The soils in these areas are saline and inherently acidic. Only saline and salt tolerant varieties are recommended in these areas.

Through four PG projects, 90 rice varieties evolved by KAU as well as local popular varieties were evaluated on the above parameters. In the study conducted at College of Agriculture, Vellayani during 1992 – 95 on the development of various quality indices for rice, among the 60 rice varieties studied, *Pokkali* variety '*Vyttila-3*' was found to be the best variety. The studies pertaining to the quality aspects of *Pokkali* rice varieties are scarce. Hence the present study is thus a relative assessment of major quality parameters of pre-released and released *Pokkali* rice varieties of Kerala Agricultural University, which will be beneficial to the breeders as well as to the consumers of the State.

The various aspects investigated are :

1. Physical and cooking characteristics of rice varieties / cultures
2. Their nutritional composition and organoleptic qualities
3. The effect of parboiling on the above quality parameters and
4. Selection of superior variety based on selected quality attributes.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The literature pertaining to the study, entitled "Quality analysis of *Pokkali* rice varieties/cultures" are reviewed under the following headings.

2.1 Structure and composition of rice

2.2 Quality aspects of rice

2.3 Effect of processing on quality aspects of rice

2.4 New technologies developed to overcome losses during processing and

2.5 Rice products.

2.1 STRUCTURE AND COMPOSITION OF RICE

Paddy has a protective layer of husk, 20-22 per cent by weight of the grain (Sharp, 1991). Vijayakhader (1997) reported that, after husk is removed, the internal kernel is called brown rice, with covering layers, pericarp, testa or seed coat and aleurone layer (Fig. 1).

According to Athmaselvi *et al.* (2001) the covering layers, removed by milling are called polishings or rice bran. Gupta *et al.* (2002) observed that, rice bran is a good source of calories as well as essential fatty acid, as it contains oil and also an excellent source of B complex vitamins and vitamin E.

Deka *et al.* (2000) found that majority of Indians are traditionally vegetarians by their dietary habits and derive most of their nutrient requirement from plant foods. Latin (2000) opined that rice (*Oryza sativa*) is the staple food of the Indian population and is mainly consumed in the form of whole grains.

Saikia (1990) reported that, on an average, one third of the calories are supplied through rice. In a study conducted by Shobarani (1992) carbohydrates, which give energy to body nearly, constitute 80

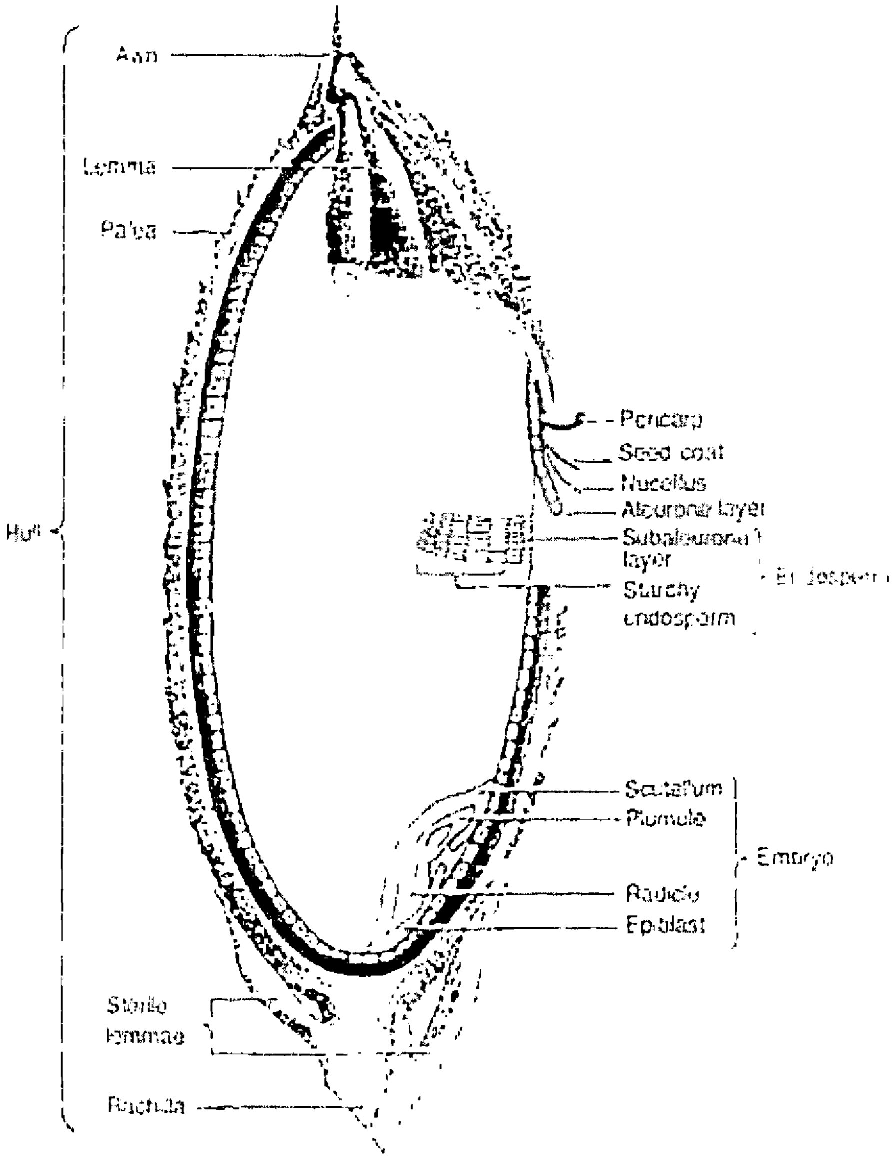

Fig. 1. Longitudinal section of rice grain

per cent of the rice grain in the form of starch. Rice is a poor source of protein as protein content is only seven per cent in rice, but it is valued as it is of superior quality (Saibaba, 1993). According to Sangha and Sachdeva (1999), rice is a fair source of vitamins and poor source of mineral salts.

Goyal and Sharma (1998) concluded that, the overall assessment of a food grain is determined by its physical, physico-chemical, nutritional, milling, cooking, processing, eating and storage qualities besides economic values.

2.2 QUALITY ASPECTS OF RICE

Quality is the degree of excellence possessed by the grain (Srivastava, 1997). From the view point of Vijayakhader (1997) to a farmer, seed quality is important, but consumer's view is influenced by local preference and food habits. The author also stated that it depends upon economic conditions, nutritive value, palatability, appearance and cooking qualities.

Veenapal and Pandey (2000) reported that, quality of rice depends upon its physical quality, which means, cleanliness, soundness and absence of foreign materials and its milling and cooking characteristics, which refer to sustainability of grain for particular end use.

Parameters like aroma, odour, and taste are very important quality characteristics, which have to be evaluated by sensory perception. In order to bring about uniformity and reliability of the test results, BIS has laid down guidelines for sensory evaluation of foods (IS 6273), and for selection of panel members (IS 8140) (Kawale, 1997).

As reported by Srivastava (1997), 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.

2.3. EFFECT OF PROCESSING ON QUALITY ASPECTS OF RICE

Milling quality of rice is based on the yield of whole kernel (head) rice, having the product of greatest economic value. The purpose of rice milling is to remove husk and bran from harvested dried paddy and to produce milled, polished or white rice with a minimum of breakage (Indudharaswamy and Bhattacharya, 1982; Pandey and Sah, 1993). Milling of paddy and factors influencing it are important technological consideration in processing of rice for the market. Veenapal and Pandey (2000) found that, milling conditions alter its physico-chemical characteristics and consumer acceptability.

Parboiling is one of the well developed pre-milling treatment given to paddy to improve quality. Parboiling of rice increases the keeping quality. The loss of protein and starch is minimal from parboiled rice while cooking. Thus parboiling enhances nutritional value of rice (Kaur and Sekhon, 1994).

According to Santha and Arulmozhi (2001) parboiling process of paddy is a hydrothermal process, which may be defined as gelatinization of the starch within the rice grain.

As reported by Pillaiyar (1981), in India, approximately 50 per cent of world paddy is parboiled and about 60 – 90 per cent of total rice consumption is in parboiled form (Choudhury, 1991).

Unnikrishnan and Bhattacharya (1995) stated that parboiling of paddy requires three steps *viz.*, soaking, steaming and drying. Several methods of parboiling are in vogue in different parts of world and the method of soaking paddy in hot water followed by open steaming (CFTRI, 1969) has been widely practiced in India, since long time (Kaur and Sekhon, 1994). Thirupathi *et al.* (2000) reported that, pressure parboiling of paddy by applying steam under pressure has been recommended, which is a method in which penetration of moisture into the paddy is in the form of water vapour under pressure which gelatinizes the starch in the kernel. The authors also concluded 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.

Kaddusmiah *et al.* (2002a) stated 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. .

Unnever *et al.* (1992) reported that the reason for stating that rice grain quality is a multidimensional character, is as it is composed of many components such as eating quality, cooking quality and nutritional quality. The authors also pointed that, each component consists of many attributes including physico-chemical properties.

2.3.1 Physical Characteristics

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 (Nandini, 1995).

The physical dimensions of rice such as, size, shape, weight and uniformity are of prime importance (Sharp, 1991). Bandhyopadhyay and Roy (1992) stated that, physical dimensions of length, breadth or width and thickness as well as shape of the kernel vary according to the variety and are considered as the most important criterion of rice quality and in developing new varieties for commercial production.

The study conducted by Ali and Bhattacharya (1980b) revealed that parboiling results in a bolder appearance after cooking. Bold grains, attractive shape, colour and lustre are also observed to be major criteria for scoring (Nirmala, 1997).

According to Rosamma *et al.* (1991), the two important characteristics about which the Kerala farmers are very specific are grain shape and kernel colour. In a study conducted by Wen Hua Ling *et al.* (2001) it was found that, red and black rice decrease atherosclerotic plaque formation and increases antioxidant status in rabbits.

As reported by Gujral and Singh (2001) higher the degree of milling, the more the bran has been removed from the kernel and thus whiter the rice The authors also opined that undermilled rice has a greater nutritional value, but has a low market appeal because most consumers prefer the appearance of white rice.

Rice is very sensitive to colour change. Biswas and Juliaono (1988) noted the influence of temperature of parboiling on the colour of parboiled rice. In a study conducted by Varadharaju *et al.* (2001), it was found that, there was appreciable change in colour due to method of parboiling. The authors also stated that parboiling, alters the colour of rice to varying extent.

Parboiling is an important pre-milling process for paddy, which brings about profound changes in various properties of rice, including changes in grain dimensions (Bhattacharya and Ali, 1985; Pillaiyar, 1988; Sowbhagya and Ali, 1991). In a study conducted by Sowbhagya and Ali (1990), a slight change in grain dimension of milled rice was observed due to parboiling. But according to Kumari and Padmavathi (1991), kernel dimensions were not useful indices for the chemical composition of rice grains. Sowbhagya *et al.* (1993) stated that, different methods of parboiling seem to affect the grain dimensions in different ways. The authors also reported that the grain length is significantly influenced by processing method.

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 6 mm. Significant variation in L/B ratio was observed for paddy, brown and milled rice (Saikia, 1990). Sheena (1997) concluded that as a result of parboiling, L/B ratio decreases significantly. 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 under similar stages of milling.

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

Significant variation in thousand kernel weight was found for paddy, brown and milled rice (Saikia, 1990). Ali *et al.* (1992) had found that split application of nitrogen fertilizer produced significantly higher thousand grain weight.

In a study conducted by Neelofer (1992), with different pre release rice cultivars, found that parboiled samples had higher values for thousand grain weight than raw rice. The thousand grain weight of high yielding varieties was higher when compared to traditional varieties (Nandini, 1995). According to Sheena (1997), parboiling significantly increased the thousand grain weight of rice varieties.

Dela and Khush (2000) opined that head rice is the milled kernels, that are 3/4 or more of endosperm length. The difference between milling yield and head rice yield is amount of broken kernels.

Indudharaswamy and Bhattacharya (1982) reported that the cause of breakage of rice grains was influenced by the properties of the grains and also by the condition under which the grains are milled. Saikia (1990) reported that medium fine grain varieties had lowest breakage.

Temperature of paddy during drying is very important for obtaining better milling quality. When the parboiled paddy was dried rapidly without tempering, a steep moisture gradient developed between the surface and centre of the kernel and causes cracking (Kaddusmiah *et al.*, 2002a). Elbert *et al.* (2001) observed high head rice yield, if drying temperature and initial tempering moisture are low.

According to Kaur *et al.* (1991) parboiling treatment of paddy varieties improved head rice recoveries and pressure parboiling, proved to be more beneficial in increasing the head rice yield and reducing the free fatty acid content. Sheena (1997) reported that parboiling significantly increased the head rice yield of rice varieties.

Kaddusmiah *et al.* (2002a) found that, with increase in soaking time, a significant increase in water absorption, milling and head rice yield in broken rice was observed. The authors also concluded that parboiling fills the void spaces and cements the cracks inside the endosperm making the grain hardened and minimizing internal fissuring and thereby breakage during milling.

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 the same period and it was reported recently by Varadharaju *et al.* (2001), that there was not much appreciable changes in swelling index due to parboiling.

2.3.2. Cooking Characteristics

Cooking quality is defined as the time required for proper cooking, the increase in volume of the cooked product, consistency and loss of solids during cooking (Bandhyopadhyay and Roy, 1992)

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) quoted that gelatinization temperature and amylose content are important starch properties which influence cooking and eating characteristics, others being kernel elongation and aroma. Cooking time is directly affected by gelatinization temperature of the starch and by protein content. According to Saikia and Bains (1993) there is significant variation in cooking time of brown and milled rice. Brown rice took longer time for cooking than milled rice.

Kaur *et al.* (1991) stated that parboiled rice required more cooking time than control, due to increased kernel hardness during the process. But, traditional parboiled rice required less time for cooking than pressure parboiled rice. According to Sowbhagya and Ali (1991) roasted parboiled rice cooks faster than normal parboiled rice, which has an additional advantage in saving time and energy for cooking. 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 optimum parboiled samples ranged between 25 – 33 and 30 – 33 minutes.

The loss of solids in cooking water generally serves as a good parameter for the assessment of cooking quality of rice (Hirannaiah *et al.*, 2001).

Rajalakshmi (1984) and Sreedevi (1989) reported that the gruel loss was higher in traditional varieties than in high yielding varieties The author also indicated a minimum loss of gruel in cooking when parboiled. This is in tune with the findings of Kaur *et al.* (1991) and Nandini (1995). According to Neelofer (1992) gruel loss was found to vary among the different rice samples after processing. More gruel loss was experienced from raw rice when compared to parboiled rice

(Nandini and Prema, 1997). Similar reports were also observed by Sheena (1997).

Kumari and Padmavathi (1991) found that volume expansion during cooking is directly affected by amylose content. The authors also opined that waxy or glutinous rice expands the least during cooking and its cooked grain has the heaviest bulk density. 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.

Nandini (1995) observed 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 the case of parboiled rice samples, when compared to raw rice samples. According to Kumari and Padmavathi (1991) volume expansion was less for short grain varieties than long grain varieties.

Saikia and Bains (1993) reported that water absorption during cooking is directly affected by amylose content. Unnikrishnan and Bhattacharya (1995) reported that, ageing through storage results in higher head rice yield, greater water absorption and volume expansion during boiling.

Water uptake ratio showed a strong negative correlation with cooking time (Tomar and Nanda, 1985). Kumari and Padmavathi (1991) observed that cooking temperature seemed to be an influencing factor on water absorption as it increased with increase in temperature. Karim *et al.* (1993) noticed that the water absorption ratio is maximum at the intermediate milling pressure by 2.0 and 2.5.

According to Saikia and Bains (1993) significant variation in water uptake ratio of brown and milled rice was noted. Nandini (1995) observed that water uptake ratio of high yielding rice varieties was found to be higher when compared to traditional varieties. 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.

Time required for cooking is determined by the gelatinization temperature of starch (Marshall *et al.*, 1993).

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 irreversibily in hot water with loss of crystallinity and birefringence. The gelatinization temperature of rice varieties may be classified as low (55 to 69^{0}C), intermediate (70 to 74^{0}C), and high (> 74^{0}C) (Dela and Khush, 2000). The authors also reported that rice varieties of intermediate gelatinization temperature are preferred all over the world, as the high gelatinization temperature rice becomes excessively soft when over cooked, elongate less and remains under cooked under standard cooking procedure. Tomar and Nanda (1985) stated that gelatinization temperature affects the water uptake, volume expansion and linear kernel elongation. Kumari and Padmavathi (1991) observed that short grain varieties showed lower spreading and clearing values than long grain varieties although some exceptions were there. According to Saikia and Bains (1993) gelatinization time and temperature at peak viscosity decreased with degree of milling.

Bandhyopadhyay and Roy (1992) studied the influence of gelatinization temperature on cooking behaviour of rice varieties and found that greater the degree of gelatinization, higher is the hydration ability of the resultant rice at temperature below 70^{0}C. The authors also concluded that above the gelatinization point, the rate of hydration decreases on parboiling, the extent of decrease was again proportional to the severity of parboiling.

Elongation ratio is the ratio of the dimension of the cooked and uncooked rice. Kumari and Padmavathi (1991) opined that grain length showed a significant negative correlation with elongation ratio. The authors also reported that short grain varieties elongated more than medium and long grain varieties, though the difference is less. Ali *et al.* (1993) stated that rice stored as milled grain improved in cooking quality as it is aged and recorded greater elongation.

The expansion ratio both along the length and breadth of parboiled rice are lower than the ratios for the raw rice cooked for same period (Sheena, 1997). Kaur *et al.* (1991) reported that parboiling treatment increases elongation ratio.

2.3.3 Nutritional Composition

Nutritional quality of rice is of primary consumer interest and milling processes designed to produce a white and acceptable commodity, result in loss of nutrients (Misaki and Yasumatsu, 1985).

Chattarjee and Maiti (1985) reported that there is an ever-growing need for grain to meet the energy and protein requirements. Rice provides upto 75 per cent of the dietary energy and protein for 2.5 billion people (Juliano, 1990). The author also reported that rice provides 68 per cent of the total energy and 69 per cent of the total dietary protein in South Asia

In a study conducted by Sreedevi (1989) using 13 varieties of rice, revealed that high yielding rice varieties evolved by Kerala Agricultural University were found to be richer sources of calories when compared with local / traditional varieties. The author also observed that the calorific value was increased after parboiling. Similar findings were also reported by Nandini (1995) and Sheena (1997).

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

According to Athmaselvi *et al.* (2001) the covering layers, namely pericarp, testa or seed coat and aluerone layer are fibrous and contain phytin, which interfere in absorption of protein and makes rice difficult to cook. Kaur and Sekhon (1994) observed that rice among the cereals, has been reported to have relatively good amino acid pattern and its PER value varies from 1.38-2.56 depending upon variety. Negative correlation between content of protein and starch, protein and volume expansion and protein percentage and water uptake were observed (Juliano, 1998). Saikia (1990) reported significant variation in protein for brown and milled rice. Sikka *et al.* (1993) found that with increasing doses of nitrogen fertilizer, there was an increase in protein content

Wimberley (1983) stated that parboiled rice retains more protein and thus is more nutritious than raw milled rice. According to Nandini (1995) the protein content dropped slightly after parboiling, because of leaching out of non-protein nitrogen and also due to decrease in the total amino acids.

According to Juliano (1998), starch is the major constituent of rice, as starch and protein are 98.5 per cent of the constituents of milled rice. Starch, a polymer of glucose occurs in the endosperm as compound polyhedral granules, three to ten microns in size (Kaddusmiah *et al.*, 2002b).

Aberg (1994) found that starch is the nutritional reservoir in plants. The author also reported that protein is negatively correlated to starch content.

Singh (1993) stated that starch is a mixture of amylose and amylopectin. Kaddusmiah *et al.* (2002b) observed that starch granules are fairly 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 hydro dynamic volume of starch increases because of irreversible swelling *ie.*, gelatinization.

The physico-chemical properties of starch as measured by amylose content, and gelatinization temperature, largely decide the cooking quality of rice (Sood and Siddiq, 1980). According to Marshall *et al.* (1993) variability in positive correlation was observed between percentage starch content and the volume expansion of the rice kernel. The authors also reported that the degree of starch gelatinization is responsible for many of the attributes in parboiled rice. Kaddusmiah *et al.* (2002b) observed that the degree of gelatinization of starch, a physical, chemical and biological parameter, is important in milling rice quality, as it was found to increase on increasing soaking time.

Marshall *et al.* (1993) opined that incomplete parboiling result in partial surface starch gelatinization. The dried kernels produced translucent outer layers and an opaque or white centre from the non gelatinized starch. The authors also stated that completely gelatinized parboiled rice kernels are translucent. Neelofer (1992) and Nandini (1995) reported that starch content of rice varieties were decreased as a result of parboiling.

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 amylopection in the rice grain. Amylose content is the principle factor for the rice quality which causes great increase in volume, water uptake ratio, texture and gloss of cooked rice (Juliano, 1990). Ram *et al.* (1998) noted a linkage between amylose content, L/B ratio and gelatinization temperature. Hermansson and Svegmark (1996) reported that, during the process of gelatinization, amylose molecules leach out of the micellar network and diffuse into the surrounding aqueous medium outside the granules.

Hot water insoluble amylose content of rice is the key determinant of the varietal differences in the texture of the cooked raw rice (Bhattacharya *et al.*, 1982). According to Unnikrishnan and Bhattacharya (1988) insoluble amylose and cooked rice firmness were correlated. Sowbhagya *et al.* (1987) and Kaur *et al.* (1991) concluded that the firmness of cooked rice increases and its stickiness decreases, as insoluble amylose content of the variety increases and vice versa. Radhika *et al.* (1993) observed that the insoluble amylose is an index of the long outchains of its amylopectin molecule.

Unnikrishnan and Bhattacharya (1995) opined that insoluble amylose content may be an intrinsic basic quality attribute of rice, irrespective of variety, ageing and parboiling. The authors also reported that the estimated value of insoluble amylose increases, when the rice is parboiled or aged or both. According to Kaur *et al.* (1991), parboiling process increases the amylose content compared to control.

The amylose / amylopectin ratio is the major factor influencing water absorption and volume expansion during cooking, as well as the texture and gloss of boiled rice. As reported by Bhattacharya *et al.* (1982) amylose/amylopectin ratio and gelatinization temperature are independent properties of rice starch, which influences eating quality. Amylose content ranges from 9-37 per cent in the starch, corresponding to 63-91 per cent amylopectin. Amylose content is therefore an index of amylose /amylopectin ratio (Dela and Khush, 2000).

Takahash *et al.* (2001) suggested that during starch gelatinization, water molecules are incorporated into the soluble high density amylopectin molecule resulting in swelling of the starch and changes it to a soluble structure with low molecular density.

Grain should be dried to 14 per cent approximately to avoid losses due to breakage in milling (Nandini, 1995). Kunze (2001) stated that moisture re-adsorption by low moisture *ie.* dried grain causes starch to expand and produce compressive stresses that can lead to fissured grain which usually break during milling.

During soaking, when grain moisture exceeds 30 – 32 per cent, then husks split causing leaching and ultimately de-shaping the rice. High temperature soaking should be strictly monitored and stopped at appropriate point when moisture content of the rice is about 30 per cent (Bhattacharya, 1985). Ramalingam and Raj (1996) stated that paddy is generally soaked in cold water for 24-48 hrs, which produced a high population of anaerobic bacteria, lactic acid bacteria, staphylococii and yeast. The authors also reported that this period of soaking and use of same water repeatedly produces off odour, poor quality and bad taste to final product.

According to Saikia (1990) milling interaction is greatly affected by variety and environment of growth, time of harvest, field moisture content, storage conditions and drying temperature.

Bandhyopadhyay and Roy (1992) found that head rice yield of a variety depends upon moisture content of grain during harvest. The authors also reported that paddy harvested at high moisture content (21-24 % wet basis) and dried by a mechanical drier gives better yield of milled rice when compared to paddy dried in the sun. Sheena (1997) reported that due to parboiling, moisture content was found to be decreasing.

De Vries *et al.* (1999) opined that dietary fibre consists of the remnants of edible plant cells, polysaccharides, lignin and associated substances resistant to hydrolysis by the digestive enzymes of humans. Feldheim and Neues Von den (1990) stated that an increased daily intake of approximately 30 g of fibre is encouraged to promote health benefits associated with fibre components. Mirko *et al.* (2001) reported that cereals form quantitatively most important sources of dietary fibre in many industrialized countries.

In a study conducted by Eggum *et al.* (1983) and Knudsen and Munch (1985), the dietary fibre content was increased on heat processing. Siljestrom *et al.* (1986) observed that different thermal processing used in the preparation of cereals for human consumption resulted in redistribution of insoluble to soluble dietary fibre. The authors also indicated an increase in soluble dietary fibre fraction after thermal processing, probably due to physical disruption of cells.

Studies conducted by Topping *et al.* (1991) reported that the Non Starch Polysaccharide (NSP) content of white rice was significantly higher than brown rice. According to Devi and Geervani (2000) varietal difference has no implication on increase in dietary fibre. The authors also stated that the dietary fibre content has decreased as a result of parboiling.

Rice is reported to be moderate source of minerals. Sood *et al.* (1980) reported that rice bran contained maximum calcium, potassium, magnesium and phosphorus, while milled rice, contains the lowest level in all the rice varieties studied. According to Atmaselvi *et al.* (2001) the phytin content interferes the absorption of minerals like calcium and iron. In a study conducted by Singh *et al.* (2000), using four Indian rice varieties which differ in shape for evaluating ash distribution pattern, revealed that all of them differed significantly with respect to percentage loss of ash content at various milling stages.

Santha and Arulmozhi (2001) reported that parboiled rice retains more vitamins and minerals and thus is more nutritious than raw milled rice. According to Sangha and Sachdeva (1999), calcium content of some studied varieties ranged from 15.96 to 24.80 mg/100g, while that of phosphorus, 149.12 to 244.83 mg/100 g and iron content 40 to 70 ppm. The authors also opined that the variation in trace element composition of rice may be attributed to various factors *viz.*, availability of soil nutrients during crop growth, diverse sampling preparation and analytical methods used by various investigations.

Parboiling process positively influences the calcium content of rice varieties (Pillaiyar, 1988; Nandini, 1995). Nandini (1995) found that phosphorus content of parboiled rice was higher compared with that of raw milled rice but Sreedevi (1989) had reported a decrease in phosphorus content during parboiling. Neelofer (1992) and Nandini (1995) reported that iron content was found to be retained more in parboiled rice samples when compared to raw rice samples. Studies of Koga *et al.* (2001) suggested that climatic factors affect mineral composition particularly Na, P and K contents of polished rice.

2.3.4 Organoleptic Qualities

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 Shadaksharaswamy, 2001).

The ratio of amylose to amylopectin in starch, as indexed by amylose content is the chief influence on eating quality (Araullo *et al.*, 1976). It correlates negatively with taste panel scores for cohesiveness, tenderness and gloss of the boiled rice (Chatterjee and Maiti, 1985).

Mundy *et al.* (1989) reported that new rice varieties need evaluation for their suitability for specific end uses in commercial applications and consumer preferences. Grain length, elongation ratio, gel length, amylose and protein content are some of the characteristics of rice used for predicting palatability of rice (Nirmala, 1997).

Sowbhagya *et al.* (1993) stated that parboiling has direct influence on consumer appeal and its acceptance. The authors also reported that although individual preferences may exist among different sectors of consumers, finer rice is normally preferred. Roasted parboiled rice had a finer appearance as compared to normal parboiled rice and may have a better consumer appeal.

According to Kumari and Padmavathi (1991) all the sensory evaluations were highly correlated positively with each other. The authors also reported that flavour was found to be most strongly positively correlated with overall quality followed by cohesiveness, appearance and texture, the important factors which affect the palatability of a particular rice variety. According to Ramarathanam and Kulkarni (1983) and Daliwal *et al.* (1990), the rice lipids are liable to oxidation and on hydrolysis during storage, contribute to the flavour characteristics of the aged rice.

Neelofer (1992) reported that parboiled rice samples were preferred most for their taste and flavour. Bandhyopadhyay and Roy (1992) stated that the flavour of the parboiled product is the result of hydrolysis and decomposition of certain constituents such as carbohydrates and proteins under the influence of steam at high temperature, during parboiling. The authors also concluded that the secondary products responsible for the characteristic flavour are the proteins consisting of the sulphur containing amino acids which produce sulphurous compounds (mercaptans).

According to Ramesh *et al.* (2000), the factors affecting texture and eating quality of cooked rice include genetic variation *eg.*, varietal related differences in amylose content, pasting characteristics, protein content, alkali degradation and gelatinization properties. Yifang and Corke (2002) stated that amylose content influences the texture of cooked rice.

According to Fumio (2000) the main ingredients that affects the taste of rice are protein, starch, water and fat content. The author found that lower the protein, better the taste, lower amylose content, means more viscosity and vice versa, when moisture content of rice drops to below 14 per cent, the taste drops as well and when rice gets old, the fat turns rancid and releases a peculiar odour which becomes an undesirable part to the taste. Studies of Asano *et al.* (2000) suggested that late harvest of rice improved taste due to decrease in number of green kernelled rice grains and content of protein and amylose.

2.4 NEW TECHNOLOGIES DEVELOPED TO OVERCOME LOSSES DURING PROCESSING

Rice processing loss is high in Asia (Haque *et al.*, 1997). The outcome of the new technologies has brought dramatic increase in the crop yield, global per capita food production has increased 140 per cent over last 50 years keeping pace with population growth, which has doubled to its current level of about 6 billion people (Charles, 2001).

2.4.1 Enrichment and Fortification

The purpose of rice enrichment and fortification is to restore to milled rice, the levels of vitamin B and minerals removed from the grain during milling.

Lee *et al.* (2000) stated that rice fortified with ultra rice™ containing retinyl palmitate was tested as a potential vehicle for vitamin A delivery.

The work done by Hettiarachchy *et al.* (1996) reported a method of calcium fortification of milled rice. The results revealed that fortification process met the US standards for calcium-fortified rice (110 –220 mg / 100 g rice) and resulted in minimal washing losses.

According to Romera *et al.* (2000) brown rice should be fortified with high levels of iron than white rice, as iron availability is reduced by the presence of phytic acid. Haas *et al.* (2000), in a survey conducted on field trials of iron enhanced rice, resulted in positive results in people where there is high prevalence of iron deficiency and consuming rice as staple food.

2.4.2 Biotechnology

Charles (2001) stated that of all the technologies used to increase the global food supply in the last millennium plant genetics and crop breeding has a greatest impact. Sehgal and Chouhan (2000) opined that biotechnology applied to food production and processing clearly encompasses a very long and diverse fields. The authors also reported that capabilities of biological systems are being utilized rapidly into a variety of food applications and consequently many new food sources, processed products are being developed.

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 anti nutritional factor in rice, increase in lysine content of rice by genetic engineering, production of transgenic rice containing β carotene.

One of the major technology of biotechnology to genetically modify foods is 'Genetic engineering'. Sehgal and Chouhan (2000) reported that the basic principle of genetic engineering is that genetic material (DNA) can be transferred from a cell of one species to another unrelated species and made to express itself in the recipient cells.

Rice grains contain 16 KDa globulion protein that is heat stable and resists proteolytic enzymes in human gut. A study conducted by Kato *et al.* (2000) on protein enhancement in rice grains results using biotechnology showed positive results. 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 from 49 per cent of rice flour to 91 per cent.

Grains and legume staples are rich in phytic acid, which is a potent inhibitor of iron absorption (Hurrell *et al.*, 1992). Studied conducted by Paola *et al.* (2001) reported that to increase iron bioavailability, thermo tolerant phytase can be introduced into the rice endosperm. In addition, as cysteine peptides are considered as major enhancer of iron absorption, endogenous cysteine rich metallothionine like protein can be over expressed. The authors concluded that such rice with an increased iron content has a great potential for substantially improving the nutrition in rice eating population.

Hamada (2000) reported that ultrafilteration process with KDa molecular cut off (MWCo) method for recovering high value components from rice bran for many industrial applications.

According to Chander *et al.* (2001), a simple flat solar air treating module by using cheap rate materials like thermocol and aluminium sheet was developed for insect disinfection of food, as a novel approach for preserving food materials especially in countries like India, where plenty of sunshine is available. Kaasova *et al.* (2001) reported a combination of microwave treatment and conventional drying of rice can be recommended due to the reduction of drying time and stability of total starch content during micro wave treatment.

Onishi *et al.* (2001) reported that improvement of eating quality and preservability of cooked rice, can be obtained from aged grain by weak electrolysed cathode water.

2.5 RICE PRODUCTS

Processed rice products may be derived from rough rice, brown rice, milled rice, cooked rice, brokens, drymilled flour, wet milled flour or rice starch (Juliano and Hicks, 1993). 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.

Juliano (1993) suggested that pre cooked rice is used for rice based convenience food products in which non rice ingredients are packed separately and mixed only during heating. Hyllstam *et al.* (1998) proposed the method of processing rice to provide a quick cooking rice.

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).

A process for the manufacture of reconstitutable rice grains was developed by Dupart *et al.* (1999) and is based on cooking a mixture of rice flour, water and hydrogenated oil in a cooker-extruder to produce a partly gelatinized mixture into rice grain shaped pieces and drying and cooling the pieces to room temperature.

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).

According to Kemp and Hopkins (1999), refrigerated rice meals involves mixing of cooked rice with oil to form a rice mixture, placing this mixture in a hermatically sealed container to form a packaged rice meal, heating the packaged rice to more than 165^{0}F, cooling to temperature less than 41^{0}F. The resultant product will have a shelf life of at least 90 days at temperature about 41^{0}F.

Piriya Thai Food Co. Ltd (1999) were able to produce ready to eat canned rice from scented long and slender jasmine grains cooked to soft texture with their natural aroma and can be stored for two years.

Juliano and Sakurai (1985) observed that fermented rice products are prepared from various waxy rices by fermenting steamed waxy milled rice with fungi and a yeast starter. Wang *et al.* (2000) produced Anka (red rice, produced by fermenting rice with *Monascus* spp.), which is used as traditional Chinese medicine to promote digestion and blood circulation. The authors suggested that it is also used to suppress hyper triglyceridaemia and hyper lipidaemia in humans.

Bean and Nishita (1985) developed successfully baked rice products for those suffering from celiac disease. The authors have developed these products from yeast leavened bread, 75 parts water, 7.5 parts sugars, 6 parts oil, 3 parts fresh compressed yeast, 3 parts hydroxypropyl methyl cellulose and two parts salt.

Wet milled non waxy or waxy rice flour kneaded with water and converted to sweetened rice cake by adding sugar and other ingredients before steaming was proposed by Juliano (1993). The author also reported that rice flour is made from waxy and non waxy rice and both raw and gelatinized rice.

According to Bryant *et al.* (2001), the main difference in the *invitro* digestion profiles of the flour was due to temperature factor. The authors suggested that the flours extruded at 100^0C were digested more slowly than those at 125 and 150^0C. Kadan *et al.* (2001) proposed preparation of rice fries. Extruded rice flour shaped and fried, reduces fat, as an alternative to conventional french fries. The authors also opined that rice fries has 12 – 50 per cent less fat than potato fries.

Chia-mao and An-I-Yeh (2001) opined that rice can be made into snack foods using extrusion cooking techniques.

According to Juliano and Sakurai (1985) puffed and popped rices are traditional breakfast cereals and snack foods. Vijayakhader (1997) found that raw rice is traditionally popped by heating rough rice (13 to 17 per cent moisture) at about 240^0C for 30 to 35 sec or at 275^0C for 40 to 45 sec or in an oil bath at 215 to 230^0C.

Rice noodles are an important part of the diet in many oriental countries His-Mei Lai (2001). Frame (1996) reported that flat and extruded round noodles and rice paper are traditionally prepared from wet milled flour that has been ground using either a stone or a metal mill.

Instant rice nectar was prepared for a long time still maintaining its taste and characteristic flavour by Jung-Man *et al.* (1998).

According to Mishra *et al.* (2000) hurum is an expanded rice product made from waxy rice. Steps involved in preparation are fully soaking of paddy, parboiling, dehusking of paddy at high moisture, immediate flaking, rubbing of fat to the flaked rice and expansion in sand.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Quality analysis of *Pokkali* rice varieties / cultures" encompasses assessment of physical, cooking, nutritional and organoleptic qualities of three released and seven cultures of *Pokkali* rice varieties of Kerala Agricultural University.

3.1 MATERIALS SELECTED

Three released *Pokkali* rice varieties and seven cultures were selected for the study. The varieties / cultures are presented in Table 1.

Table 1. Rice varieties / cultures selected

Released varieties	Cultures
Vyttila-2	*Culture-1026*
Vyttila-4	*Culture-1734*
Vyttila-5	*Culture-2006*
	CIRJ- 7
	CIRJ- 8
	CIRJ- 9
	CIRJ-19

One to one and a half kg of the above rice varieties / cultures were collected from the Kerala Agricultural University, Rice Research Station, Vyttila and were processed into two types *ie.*, raw milled and parboiled milled and the samples obtained after milling were stored in airtight steel containers for various laboratory studies.

3.2 QUALITY PARAMETERS SELECTED

A detailed study of different quality parameters of rice *viz.*, (a) physical characteristics (b) cooking characteristics (c) nutritional composition and (d) organoleptic studies were envisaged.

Under each parameter, a number of indicators are available. Among these parameters, physical characteristics and cooking characteristics influence the consumer appeal immediately, while the organoleptic quality positively influences the popularity of the rice in the long run. Parameter like nutritional composition has little influence on the popularity of the rice varieties among consumers. 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. Size : For determining size, the rice samples were classified into three categories *ie.*, extra bold, bold and medium bold as per the method suggested by FAO (1970).

b. Colour : Colour of the rice varieties / cultures was ascertained by direct observation.

c. Shape : Shape of the rice varieties was determined by classifying them, according to length – width ratio. 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).

i. Slender, long grain rice – L/B ratio > 3.0

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

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

d. Length – Breadth ratio : Length – Breadth (L/B) ratio of rice varieties was estimated as per the method outlined by Pillaiyar and Mohandoss (1981a).

e. Thousand grain weight : Thousand grain weight of different rice samples was determined by weighing one thousand rice grains randomly selected (Sindhu *et al.*, 1975). An electronic balance was used for recording thousand grain weight.

f. Swelling capacity / seed : Swelling capacity is the ratio of the final to the initial volume or weight of the rice. It was determined by the method suggested by Sood *et al.* (2002)

g. Swelling index : Swelling index of different rice sample was determined by the method of Sood *et al.* (2002).

h. Head rice yield : Head rice yield of different rice samples was determined as per the method suggested by Rajalakshmi (1984).

3.2.2 Cooking Characteristics

Cooking and eating qualities vary with consumer acceptance in different parts of the world and they are decided by various indices, as furnished below.

a. Optimum cooking time : Optimum cooking time was estimated by the method outlined by Bhattacharya and Sowbhagya (1971).

b. Volume Expansion : Volume expansion or kernel expansion is determined from the ratio between the cooked volume of rice to that of uncooked rice. It was estimated by the method suggested by Pillaiyar and Mohandoss (1981b).

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

d. 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 by the method suggested by Sanjiva Rao *et al.* (1952).

e. Elongation ratio : Elongation ratio is the ratio between the length of cooked grain and that of the raw grain. It was measured by the method outlined by Pillaiyar and Mohandoss (1981c).

f. Gelatinization temperature : Gelatinization temperature of rice varieties was estimated by the method suggested by Mac Masters (1964).

g. Elongation index : Elongation index is the ratio between the length and width of cooked grain and that of uncooked grain. Method of Sood and Siddiq (1980) was used for the determination of elongation index of milled rice (both raw and parboiled).

3.2.3 Nutritional Composition

The major nutrients analysed in the raw and parboiled samples were listed below:

a. Energy : Energy or calorific value was estimated using a Bomb Calorimeter as per the method outlined by Swaminathan (1984).

b. Protein: The protein content was estimated by Kjeldahl's wet digestion method of Hawk and Oser (1965).

c. Starch : Starch was estimated by the ferricyanide method suggested by Aminoff *et al.* (1970).

d. Fibre : Crude fibre content was estimated by the method of Raghuramalu *et al.* (1983).

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

f. Iron : The iron was estimated in an atomic absorption Spectrophotometer by feeding the triple acid digest of the sample prepared into an AAS (Jackson, 1973).

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

h. Amylose : Total amylose content was estimated by the method of Mc Cready and Hassid (1943).

i. Amylose-Amylopectin ratio : Amylose – Amylopectin ratio of different rice samples was estimated by the method of Mc Cready and Hassid (1943).

j. Moisture : Moisture content was estimated by the method of AOAC (1990).

k. Sodium : Total sodium concentration of samples was determined from the triple acid extract in an EEC Flame Photometer (Jackson, 1973).

l. Potassium : Total potassium concentration of the samples was determined from triple acid extract in an EEC Flame Photometer (Jackson, 1973).

3.2.4 Organoleptic Qualities

Organoleptic 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.

Organoleptic qualities of different rice varieties, both raw and parboiled were evaluated by a taste panel. For the acceptability trials, ten panel members were selected by using triangle test (Jellink, 1964) and the test was conducted as per the standard procedure prescribed by Swaminathan (1974) (Appendix - I). The major quality attributes such as colour, appearance, flavour, texture and taste were scored by the panel members on a five point hedonic scale (Appendix –2).

3.3 STATISTICAL ANALYSIS

Statistical analysis was carried out as follows :

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

RESULTS

4. RESULTS

The results of the study entitled "Quality analysis of *Pokkali* rice varieties / cultures" are presented under,

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, shape, colour, length, width, length/breadth ratio, thousand grain weight, and head rice yield were determined to assess the physical characteristics of rice varieties/ cultures.

Table 2 depicts shape and colour of rice varieties/ cultures. Based on length –width ratio, FAO (1970) classified the rice grains into three categories such as;

1. Slender, long grain rice -L/B ratio > 3
2. Bold, medium grain rice-L/B ratio 2 – 3
3. Round, short grain rice-L/B ratio < 2

In the present study all the three varieties and seven cultures were found to be bold.

Among the three varieties and seven cultures analysed, two varieties and four cultures such as *Vyttila-2, Vyttila-4, CIRJ-7, CIRJ-8, CIRJ-9* and *CIRJ-19* respectively were found to have red colour and cultures *Cul-1026, Cul-1734, Cul-2006* and variety *Vyttila-5* were white in colour.

Table 2. Shape and colour of rice varieties / cultures

Varieties	Shape		Colour	
	Raw	Parboiled	Raw	Parboiled
Vyttila-2	Bold, medium	Bold, medium	Red	Dark red
Vyttila-4	Bold, medium	Bold, medium	Red	Dark red
Vyttila-5	Bold, medium	Bold, medium	White	Creamish, white
Cul-1026	Bold, medium	Bold, medium	White	Creamish white
Cul-1734	Bold, medium	Bold, medium	White	Creamish white
Cul-2006	Bold, medium	Bold, medium	White	Creamish white
CIRJ-7	Bold, medium	Bold, medium	Red	Dark red
CIRJ-8	Bold, medium	Bold, medium	Red	Red
CIRJ-9	Bold, medium	Bold, medium	Red	Red
CIRJ-19	Bold, medium	Bold, medium	Red	Red

Physical dimensions of rice kernels such as length, breadth or width and thickness as well as size and shape of the rice kernels are of vital interest to those engaged in rice industry (Dela and Khush, 2000). These qualities may vary from variety to variety.

Table 3 presents the length, width and length /breadth ratio of the rice varieties. Length of the grain is measured in its greatest dimension, width along the ventral side and thickness across the dorsal side. In the present study, length and width varied significantly among the varieties. The length was found to be highest for the *Cul-2006* (6.77 mm) and lowest for the variety *Vyttila-5* (5.51 mm)

When statistically analysed, there was significant difference between the rice varieties. Parboiling significantly decreased the length of rice varieties. The length was found to be ranging from 5.47 to 6.93 mm in raw rice varieties and between 5.23 to 6.60 mm in parboiled rice varieties.

The width was found to be ranging from 2.36-3.00 mm in raw rice and 2.27-2.67 mm in parboiled rice. The width was found to be highest for variety *Vyttila-4* (2.83mm) and lowest for *Cul-1026* (2.32 mm).

There was significant difference between the varieties for width and also between the width of raw and parboiled varieties. Parboiling

Table 3. Length, width and L/B ratio of rice varieties / cultures

Varieties	Length (mm)			Width (mm)			L/B ratio		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	5.80	5.40	5.60	2.80	2.67	2.73	2.07	2.02	2.05
Vyttila-4	6.10	5.80	5.95	3.00	2.67	2.83	2.03	2.18	2.11
Vyttila-5	5.80	5.23	5.51	2.60	2.53	2.57	2.23	2.07	2.15
Cul-1026	6.53	6.33	6.43	2.36	2.27	2.32	2.76	2.79	2.78
Cul-1734	5.93	5.63	5.78	2.43	2.43	2.43	2.44	2.32	2.38
Cul-2006	6.93	6.60	6.77	2.77	2.53	2.65	2.52	2.61	2.56
CIRJ-7	5.60	5.73	5.67	2.57	2.67	2.62	2.18	2.16	2.17
CIRJ-8	5.47	5.80	5.63	2.57	2.47	2.52	2.13	2.35	2.24
CIRJ-9	6.00	5.93	5.97	2.50	2.63	2.57	2.40	2.25	2.33
CIRJ-19	5.77	5.83	5.80	2.40	2.50	2.45	2.40	2.33	2.37
Mean	5.99	5.83		2.60	2.53		2.32	2.31	
Varieties									
F value		49.17*			14.61*			25.72*	
SE		0.05			0.03			0.04	
CD		0.162			0.112			0.126	
Processing									
F value		20.69*			6.45*			0.088*	
SE		0.025			0.01			0.019	
CD		0.072			5.041			0.056	
Variety x Processing									
F value		5.882*			3.66*			2.16*	
SE		0.080			0.05			0.062	
CD		0.229			0.159			0.178	

* Significant at 5 % level

process was found to significantly decrease the width of the rice varieties.

Length/breadth ratio varied significantly between the different varieties. The highest length/breadth ratio was recorded for *Cul-1026* (2.78) and lowest for the variety *Vyttila-2* (2.05). In raw rice, the L/B ratio ranged between 2.03 – 2.76 and in parboiled rice, it was between 2.02 – 2.79.

The statistical analysis of the data also revealed that, there was no significant difference between the L/B ratio of rice varieties with respect to processing method.

Table 4 represents thousand grain weight and head rice yield of the rice varieties.

Table 4. Thousand grain weight and head rice yield of rice varieties / cultures

Varieties	Thousand grain weight (g)			Head rice yield (%)		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	24.20	24.80	24.50	75.75	76.50	76.12
Vyttila-4	22.70	25.30	24.00	75.50	81.10	78.30
Vyttila-5	21.70	21.70	21.70	77.00	79.50	78.25
Cul-1026	20.30	20.60	20.50	65.14	66.63	65.88
Cul-1734	18.50	18.20	18.40	73.05	75.05	74.05
Cul-2006	22.60	22.20	22.40	72.95	76.67	74.81
CIRJ-7	21.30	22.70	22.00	70.00	80.90	75.43
CIRJ-8	22.00	23.70	22.80	70.00	80.00	75.00
CIRJ-9	21.30	24.70	23.00	78.50	80.00	79.25
CIRJ-19	23.30	23.30	23.30	70.00	80.00	75.00
Mean	21.80	22.70		72.79	77.63	
Varieties						
F value	55.63*			31.31*		
SE	0.023			0.66		
CD	0.068			1.961		
Processing						
F value	36.06*			132.84*		
SE	0.01			0.29		
CD	0.030			0.877		
Variety x Processing						
F value	7.16*			9.08*		
SE	0.033			0.94		
CD	0.096			2.773		

* Significant at 5 % level

Values for thousand grain weight was recorded highest for the variety *Vyttila-2* (24.20 g) for raw rice varieties and lowest being observed in *Cul-1734* (18.50 g). In the case of parboiled rice varieties, highest value was noted in variety *Vyttila-4* (25.30 g) and lowest in *Cul-1734* (18.20 g). The thousand grain weight values ranged between 18.50 – 24.20 g in raw rice and between 18.20 – 25.30 g in parboiled rice samples.

The thousand grain weight was found to vary significantly. The data when statistically analysed, revealed that there exists significant difference between the varieties. The thousand grain weight was found to vary significantly after parboiling. Parboiled samples had significantly higher thousand grain weight values compared to raw rice samples.

The data also revealed a significant interaction between the varieties and the processing method with exceptional cases like *Cul-1026, Cul- 1734, Cul-2006* and *CIRJ-19* which were on par.

The head rice yield was found to be ranging from 65.14 – 78.50 per cent in raw rice and 66.63 – 81.10 per cent in parboiled rice samples.

The highest percentage of head rice yield was observed for the *Cul CIRJ-9* (79.25 %) and the lowest value for *Cul-1026* (65.88 %).

Statistical analysis of the data revealed that there was a significant difference between the rice varieties in terms of head rice yield.

Significant difference also exists between raw and parboiled samples with respect to processing method applied.

Table 5. Swelling capacity and swelling index values of rice varieties / cultures

Varieties	Swelling capacity (ml / seed)			Swelling index		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	0.01	0.017	0.014	0.37	0.70	0.54
Vyttila-4	0.01	0.01	0.01	0.40	0.41	0.41
Vyttila-5	0.01	0.01	0.01	0.46	0.69	0.58
Cul-1026	0.01	0.02	0.01	0.44	1.22	0.83
Cul-1734	0.01	0.02	0.012	0.45	1.80	1.13
Cul-2006	0.01	0.03	0.012	0.44	1.63	1.04
CIRJ-7	0.01	0.03	0.012	0.46	1.30	0.88
CIRJ-8	0.01	0.03	0.012	0.50	1.25	0.88
CIRJ-9	0.01	0.03	0.011	0.53	1.33	0.93
CIRJ-19	0.007	0.03	0.019	0.32	1.33	0.83
Mean	0.010	0.025		0.44	1.16	
Varieties						
F value	4.49*			6.72*		
SE	0.001			0.08		
CD	0.005			0.26		
Processing						
F value	159.35*			172.49*		
SE	0.008			0.03		
CD	0.002			0.114		
Variety x Processing						
F value	4.91*			5.83*		
SE	0.002			0.12		
CD	0.007			0.36		

* Significant at 5 % level

Table 5, reveals the swelling capacity and swelling index of rice varieties. Swelling capacity per seed was found to range from 0.007 to 0.01 in raw rice varieties and 0.01 to 0.03 in parboiled rice varieties.

Statistical analysis revealed that there was significant difference between the rice varieties and also between raw and parboiled samples in terms of swelling capacity / seed.

Swelling index was found to range between 0.32 to 0.53 in raw rice samples and 0.41 to 1.80 in parboiled samples. Highest value for swelling index was observed in *Cul-1734* (1.13) and lowest in *Vyttila-4* (0.40). Significant difference exists between rice varieties and processing method applied. Interaction between varieties and processing method was also found to be significant.

4.2 COOKING CHARACTERISTICS

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

Table 6, presents details on optimum cooking time and gruel loss of the rice varieties.

Table 6. Time taken for cooking and gruel loss of rice varieties / cultures

Varieties	Optimum cooking time (min)			Gruel loss (%)		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	35.00	37.50	36.25	1.50	1.45	1.47
Vyttila-4	19.00	25.00	22.00	3.60	2.94	3.27
Vyttila-5	24.00	27.50	25.75	2.45	0.75	1.60
Cul-1026	20.00	19.00	19.50	2.10	1.20	1.65
Cul-1734	20.00	19.00	19.50	1.65	0.60	1.12
Cul-2006	18.00	17.50	17.75	1.95	0.90	1.42
CIRJ-7	20.00	22.50	21.25	1.85	1.50	1.67
CIRJ-8	23.00	23.50	23.25	1.65	1.10	1.37
CIRJ-9	22.50	32.50	27.50	1.55	1.35	1.45
CIRJ-19	21.50	27.50	24.50	2.35	2.09	2.22
Mean	22.30	25.10		2.06	1.38	
Varieties						
F value	14.76*			16.18*		
SE	1.38			0.15		
CD	4.099			0.449		
Processing						
F value	10.51*			49.29*		
SE	0.62			0.06		
CD	1.833			0.200		
Variety x Processing						
F value	1.69*			2.75*		
SE	1.96			0.21		
CD	5.798			0.635		

* Significant at 5 % level

Cooking time is one of the major determinants of the quality of rice grains and consumers prefer rice grain with lesser cooking time.

The optimum cooking time was found to be significantly different among the varieties. It was observed that the variety *Vyttila-2* took higher cooking time (36.25 min) and *Cul-2006* took lesser time (17.75 min). In the present study the optimum cooking time of the raw rice varieties ranged between 18.00 – 35.00 min.

The optimum cooking time was significantly affected by parboiling. It was observed that parboiling process increased the cooking time of rice varieties. The optimum cooking time of the parboiled rice varieties ranged between 17.50 min to 37.50 min.

The statistical analysis revealed that the interaction between the varieties and processing was found to be significant, exceptional cases being *Vyttila-4, CIRJ-9* and *CIRJ-19*, where there was significant difference between the varieties and processing method.

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

As evident from Table 6, there was a significant difference among the varieties with respect to gruel loss. Among the ten varieties the percentage of gruel loss was highest in variety *Vyttila-4* (3.27 %) and lowest in *Cul-1734* (1.12 %).

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

Table 7 presents datas on volume expansion, water uptake and gelatinization temperature of the rice varieties

Volume expansion or kernel expansion is determined from the ratio between the cooked volume of rice to that of uncooked rice. A comparison of the rice varieties revealed significant change in volume expansion.

Higher volume expansion was observed in *Cul-2006* (9.15) followed by *CIRJ-8* (9.12). The lowest expansion was observed in *Cul-1026* (6.65) followed by *CIRJ-9* (7.00).

The volume expansion for raw rice varieties was in the range, 5.80 – 9.94 and that of parboiled rice varieties, it was between 7.40 – 10.13.

Table 7. Volume expansion, water uptake and gelatinization temperature of rice varieties / cultures

Varieties	Volume Expansion (ratio)			Water uptake (ratio)			Gelatinization temperature (^{o}C)		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	5.80	10.13	7.96	3.21	4.99	4.10	75.50	68.50	72.00
Vyttila-4	7.40	9.33	8.36	3.88	5.16	4.52	75.00	72.50	73.75
Vyttila-5	7.10	8.30	7.70	4.46	6.35	5.41	77.00	72.00	74.50
Cul-1026	5.80	7.50	6.65	4.69	6.23	5.46	67.50	71.00	69.25
Cul-1734	8.90	9.25	9.07	5.35	6.36	5.85	74.50	73.50	74.00
Cul-2006	9.41	8.90	9.15	4.90	6.57	5.74	72.50	70.00	71.25
CIRJ-7	9.43	7.75	8.59	6.00	5.05	5.53	70.00	68.50	69.25
CIRJ-8	9.94	8.30	9.12	7.30	4.67	5.98	74.50	71.00	72.75
CIRJ-9	6.10	7.90	7.00	3.86	4.15	4.01	70.00	71.50	70.75
CIRJ-19	7.60	7.40	7.50	4.32	3.86	4.09	70.50	75.50	73.00
Mean	7.74	8.47		4.79	5.34		72.70	71.40	
Varieties									
F value		7.52*			2.89*			6.48*	
SE		0.32			0.46			0.74	
CD		0.968			1.380			2.187	
Processing									
F value		12.34*			3.35*			7.68*	
SE		0.14			0.20			0.33	
CD		0.432			0.617			0.978	
Variety x Processing									
F value		7.95*			2.50*			6.29*	
SE		0.46			0.66			1.04	
CD		1.366			1.951			3.094	

* Significant at 5 % level

A significant increase in volume expansion was observed when rice varieties were parboiled. The mean value of volume expansion for parboiled rice varieties was 8.47 and that of raw rice varieties, 7.74. The present study also revealed significant interaction between varieties and processing.

Water uptake is a measure of the hydration characteristics of rice. It was evident from Table 7, that the water uptake ratio's of rice varieties, were significantly different. Among the rice varieties, *CIRJ-8* possessed higher water uptake ratio (5.98) and *CIRJ-9* had the lowest (4.01).

When analysed statistically, the data revealed that there was no significant difference between the raw and parboiled rice, but it was noticeable that parboiled rice of same varieties had higher value for water uptake ratio. The mean value of water uptake ratio of raw rice varieties was 4.79, while that of parboiled rice varieties was 5.34. Statistical data revealed that no significant difference exists between the varieties and processing methods except in the case of *CIRJ-8*.

The gelatinization temperature of starch is the range of temperature, within which the starch starts to swell irreversibly in hot water with simultaneous loss of crystallinity (Govindaswamy, 1985).

A significant difference was observed in the gelatinization temperature among the different rice varieties (Table 7). As noticed from the table, the highest value for the gelatinization temperature was observed in variety *Vyttila-5* (74.5^{0}C) and lowest in *Cul-1026* and *CIRJ-7* (69.5^{0}C).

The gelatinization temperature of raw rice varieties was found to be ranging from 67.5^{0}C – 74.5^{0}C and that of parboiled rice varieties were between 68.5^{0}C to 75.5^{0}C. There was a significant difference between raw and parboiled rice varieties. A significantly higher gelatinization temperature was observed in raw rice samples compared to parboiled rice samples. The interaction between varieties and processing methods was also found to be significant except for variety *Vyttila-2*, *Cul-1734* and *CIRJ-9*.

Table 8. Elongation ratio and elongation index of rice varieties / cultures

Varieties	Elongation ratio			Elongation index		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	1.25	1.41	1.33	1.52	1.92	1.72
Vyttila-4	1.09	1.27	1.18	1.08	1.61	1.35
Vyttila-5	1.23	1.37	1.30	1.62	1.89	1.76
Cul-1026	1.16	1.24	1.20	1.63	1.74	1.69
Cul-1734	1.36	1.34	1.35	1.99	1.75	1.87
Cul-2006	1.22	1.19	1.21	1.58	1.50	1.54
CIRJ-7	1.45	1.32	1.39	2.02	1.76	1.89
CIRJ-8	1.44	1.34	1.39	1.69	1.95	1.82
CIRJ-9	1.20	1.22	1.21	1.44	1.43	1.43
CIRJ-19	1.31	1.28	1.30	1.80	1.78	1.79
Mean	1.27	1.30		1.64	1.73	
Varieties						
F value	10.92*			6.17*		
SE	0.02			0.02		
CD	0.070			0.079		
Processing						
F value	3.51*			9.67*		
SE	0.01			0.06		
CD	0.031			0.177		
Variety x Processing						
F value	4.99*			4.95*		
SE	0.03			0.08		
CD	0.100			0.250		

* Significant at 5 % level

Table 8 shows elongation ratio and elongation index of the rice varieties.

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 8.

In the present study, the highest elongation ratio was possessed by *Cul CIRJ-7* (1.39) and lowest by variety *Vyttila-4* (1.18). The elongation ratio of raw rice ranges between 1.09 to 1.45 and that of parboiled rice ranges between 1.19 to 1.41.

Parboiling process significantly increased the elongation ratio of the rice varieties. The elongation ratio mean for parboiled rice was

1.30 and that of raw rice was 1.27. The interaction between the rice varieties and processing methods was also found to be significant.

Elongation index is the ratio between the length and width of cooked grain and that of uncooked grain. This is related to grain dimension and is a measure of the percentage increase in grain dimension after cooking.

It was observed that the elongation index of the rice varieties varied significantly. The highest value for elongation index was observed for variety *CIRJ-7* (1.89) and lowest for variety *Vyttila-4* (1.35). For raw rice, elongation index ranged between 1.08 to 2.02 and for parboiled rice, it ranged between 1.43 to 1.95. Parboiling process significantly increases the elongation index of the rice varieties. The interaction between the rice varieties and processing method was also found to be significant; exceptional cases are *Cul-1026*, *Cul-1734*, *Cul-2006*, *CIRJ-9* and *CIRJ-19*.

4.3 NUTRITIONAL COMPOSITION

The calorific value, protein, starch, amylose, amylose-amylopectin ratio, moisture, crude fibre, calcium, phosphorous, iron, sodium and potassium content of the rice varieties / cultures were determined to assess the nutritional composition.

Calorific value of rice can be determined by oxidizing a known quantity of sample in a bomb calorimeter and then measuring the heat liberated.

Table 9. Calorific value and protein content of rice varieties / cultures

Varieties	Energy (kcal)			Protein (g / 100 g)		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	404	482	443	4.23	4.23	4.23
Vyttila-4	334	357	345	8.96	11.42	10.19
Vyttila-5	334	357	345	9.18	5.24	7.21
Cul-1026	334	380	357	5.52	9.83	7.68
Cul-1734	445	357	351	8.96	13.34	11.15
Cul-2006	368	461	415	8.72	5.26	6.99
CIRJ-7	345	380	363	4.65	3.98	4.31
CIRJ-8	334	357	345	8.09	15.96	12.03
CIRJ-9	345	380	363	6.99	10.05	8.52
CIRJ-19	345	380	363	7.43	10.05	8.74
Mean	349	389		7.27	8.94	
Varieties						
F value	24.72*			12.66*		
SE	6.65			0.73		
CD	19.46			2.14		
Processing						
F value	91.97*			12.89*		
SE	2.97			0.32		
CD	8.70			0.96		
Variety x Processing						
F value	3.81*			6.32*		
SE	9.41			1.03		
CD	27.52			3.03		

* Significant at 5 % level

Calorific value/energy and protein content of the rice varieties are presented in Table 9.

The calorific value was found to vary significantly among most of the rice varieties studied. The variety *Vyttila-2* was found to have highest calorific value (443 Kcal) followed by *Cul-2006* (415 Kcal) and the variety *Vyttila-4*, *Vyttila-5* and *CIRJ-8* were found to have lowest calorific value (345 Kcal). The calorific value among the ten rice varieties was found to range between 334 Kcal to 404 Kcal for raw varieties and 357 Kcal to 482 Kcal for its parboiled counterparts.

Parboiling process significantly influences the calorific value of the rice varieties. The interaction between the variety and processing method applied was statistically analysed and found out that there was significant difference in half of the varieties and no significant difference was observed in the remaing half of the varieties.

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 4.23 g to 9.18 g and that of parboiled rice was between 4.23 g to 15.96 g. Highest value of protein content was noted in *CIRJ-8* (12.03 g) and lowest in *Vyttila-2* (4.23 g).

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 8.94 g, while that of raw rice was 7.27 g. When statistically analysed, there exists a significant interaction between the rice varieties.

Table 10, represents starch, amylose, amylose-amylopectin ratio of the rice varieties. The highest value of starch content was recorded in the variety *Vyttila-4* (88.58 %)and the lowest in *Vyttila-5* (64.89 %). In raw rice varieties, starch content ranged between 63.32 – 88.75 per cent and in parboiled rice varieties, the starch content ranged between 61.34 – 94.88 per cent.

The data when analysed statistically revealed that there exists a significant difference among the varieties.

Parboiling reduced the percentage of starch content of rice varieties. The mean value for parboiled rice varieties was 76.28 per cent and that of raw rice varieties was 77.75 per cent. The interaction between the varieties and processing when analysed statistically revealed that there was no significant difference between varieties and processing.

Amylose content of rice verities / cultures varied significantly (Table 10). The highest amylose content (24.41 %) was noticed in *Cul-2006*, which was on par with variety *Vyttila-2* (23.54 %) while the lowest (15.85 %) noted in variety *Vyttila-5*, which was on par with *Cul-1026* (16.62 %).

Table 10. Starch, amylose and amylose-amylopectin ratio of rice varieties / cultures

Varieties	Starch (%)			Amylose (%)			Amylose-amylopectin ratio		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	63.32	71.59	67.46	25.23	21.84	23.54	0.67	0.43	0.55
Vyttila-4	88.58	88.58	88.58	18.51	16.74	17.62	0.27	0.23	0.25
Vyttila-5	63.50	66.28	64.89	16.74	14.96	15.85	0.35	0.29	0.32
Cul-1026	82.89	75.05	78.97	17.65	15.60	16.62	0.27	0.26	0.26
Cul-1734	79.61	94.88	87.25	21.60	19.93	20.77	0.37	0.26	0.32
Cul-2006	79.54	61.34	70.44	27.71	21.11	24.41	0.55	0.53	0.54
CIRJ-7	88.75	82.59	85.67	20.65	20.33	20.49	0.30	0.33	0.32
CIRJ-8	81.60	67.96	74.78	23.50	23.34	23.42	0.40	0.52	0.46
CIRJ-9	72.39	71.61	72.00	20.00	15.07	17.53	0.38	0.26	0.32
CIRJ-19	77.32	82.89	80.11	25.58	20.23	22.90	0.49	0.31	0.40
Mean	77.75	76.28		21.71	18.91		0.41	0.34	
Varieties									
F value		6.28*			75.75*			13.83*	
SE		3.36			0.36			0.02	
CD		9.912			1.085			0.086	
Processing									
F value		0.47*			144.93*			11.58*	
SE		1.50			0.16			0.01	
CD		4.432			0.485			0.038	
Variety x Processing									
F value		2.30*			8.81*			3.14*	
SE		4.75			0.52			0.04	
CD		14.017			1.534			0.122	

* Significant at 5 % level

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%) (Kumar and Khush, 1986).

Consumers prefer a rice grain with intermediate amylose content. Among the ten rice varieties / cultures studied, two varieties and two cultures *viz.*, *Vyttila-4* (17.62 %), *Vyttila-5* (15.85 %), *Cul-1026* (16.62 %) and *CIRJ-9* (17.53 %) belonged to low amylose group. The remaining varieties / cultures belonged to intermediate amylose group *viz.*, *Vyttila-2* (23.54 %), *Cul-1734* (20.77 %), and *Cul-2006* (24.41 %), *CIRJ-7* (20.49 %) *CIRJ-8* (23.42 %) and *CIRJ-19* (22.90 %).

A significant decrease in amylose content was observed after parboiling. This might be due to the loss of gluten into the gruel. Such negative effect of parboiling on amylose content was also reported by Sreedevi (1989), Nandini (1995) and Sheena (1997). The mean value of amylose content among the raw rice varieties was 21.71 and that of parboiled rice varieties was 18.91. The interaction between the varieties and processing method was also found to be significant.

The amylose-amylopectin ratio varied significantly among the different rice varieties (Table 10). The highest ratio was observed in variety *Vyttila-2* (0.55), which was on par with *Cul-2006* (0.54) and lowest ratio in variety *Vyttila-4* (0.25), which was on par with *Cul-1026* (0.26).

The amylose-amylopectin ratio in raw rice varieties ranged between 0.27 – 0.67, while in parboiled rice, the ratio ranged between 0.23 – 0.53 respectively. There was a slight but significant decrease in amylose-amylopectin ratio in parboiled rice (0.34) when compared to raw rice (0.41). When analysed, the data revealed that the interaction between variety and processing method was found to be statistically significant in half of the samples and in the remaining half it was not significant with respect to amylose-amylopectin ratio.

Moisture and fibre content of the rice varieties are presented in Table 11.

Table 11. Percentage of moisture and crude fibre content of rice varieties / cultures

Varieties	Moisture (%)			Crude fibre (%)		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	11.10	12.50	11.80	0.25	0.26	0.25
Vyttila-4	12.30	10.50	11.40	0.24	0.25	0.25
Vyttila-5	11.10	11.50	11.40	0.27	0.28	0.28
Cul-1026	11.50	10.70	11.10	0.27	0.29	0.28
Cul-1734	12.50	13.10	12.80	0.30	0.31	0.31
Cul-2006	11.10	12.50	11.80	0.42	0.42	0.42
CIRJ-7	10.50	12.30	11.40	0.30	0.31	0.31
CIRJ-8	10.70	11.30	11.00	0.32	0.34	0.33
CIRJ-9	10.50	12.30	11.40	0.29	0.29	0.29
CIRJ-19	11.10	12.30	11.70	0.29	0.30	0.29
Mean	11.24	11.90		0.29	0.31	
Varieties						
F value	52.09*			0.014*		
SE	0.07			0.0007		
CD	0.208			0.010		
Processing						
F value	218.11*			0.001*		
SE	0.03			0.0003		
CD	0.093			0.004		
Variety x Processing						
F value	68.12*			0.0005*		
SE	0.09			0.0009		
CD	0.294			0.014		

* Significant at 5 % level

In the present study, the moisture content was found to be ranging from 10.50 –12.50 per cent in raw rice and 10.50 – 13.10 per cent in parboiled rice varieties. Highest moisture content was observed in *Cul-1734* (12.80 %) and lowest in variety *CIRJ-8* (11.00 %). When analysed statistically, the data revealed that there exists significant difference among the rice varieties.

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 11.24 and that of parboiled rice, it was 11.90. The interaction between the varieties and processing method was also found to be significant with respect to moisture content.

It was observed that there was a significant difference among the varieties. The crude fibre content of rice varieties ranged between 0.24 to 0.42 per cent in raw samples. The highest fibre content was observed in *Cul-2006* (0.42 %) and the lowest in variety *Vyttila-4* (0.25 %). Statistical analysis of data revealed that parboiling significantly influenced the crude fibre content of the rice varieties. The fibre content of the parboiled samples ranged between 0.25 to 0.42 per cent. Similar to raw rice, in parboiled rice also, the highest fibre content was observed in *Cul-2006* (0.42 %) and the lowest in *Vyttila-4* (0.25 %).

Calcium, phosphorus and iron content of the rice varieties were estimated and are depicted in Table 12. The statistical analysis of the data revealed that there exists a significant difference for Ca content among the rice varieties. Highest value for calcium content was observed in *Cul-1026* (15.84 mg). *Cul-1026* is almost on par with *CIRJ-7* (15.36 mg). Lowest value for calcium content was noted in *Cul-1734* (7.68 mg). Calcium content in raw rice ranges between 6.72 mg – 15.36 mg.

Parboiling significantly increased the calcium content in the rice varieties. Mean value noted for parboiled rice was 12.91 mg and that of raw rice was 12.07 mg. The calcium content in parboiled rice ranges between 8.64 mg to 16.56 mg. The highest calcium content after parboiling was noticed in *Cul-1026* (16.56 mg) and the lowest value in *Cul-1734* (8.64 mg).

Phosphorus content of raw rice ranges from 178.25 mg – 341.85 mg, while that of parboiled rice ranges between 96.45 mg – 212.75 mg (Table 12). A significant difference was observed in phosphorus content of rice varieties. Highest value of phosphorus content was noticed in *Cul-1734* (237.05 mg) and lowest in variety *Vyttila-2* (144.08 mg). Statistical analysis of the data revealed that due to parboiling, there was a significant decrease in phosphorus content of rice varieties when compared to raw rice. The mean value noted for parboiled rice was 155.4 mg and that of

Table 12. Calcium, phosphorus and iron content of rice varieties / cultures, mg / 100g

Varieties	Calcium			Phosphorus			Iron		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	11.52	13.92	12.72	191.70	96.45	144.07	1.60	0.82	1.21
Vyttila-4	11.52	12.72	12.12	221.15	148.58	184.87	0.80	0.38	0.59
Vyttila-5	12.96	12.24	12.60	178.25	201.30	189.78	0.91	0.45	0.68
Cul-1026	15.12	16.56	15.84	248.80	138.06	193.43	0.94	0.50	0.72
Cul-1734	6.72	8.64	7.68	341.85	132.25	237.05	0.81	0.49	0.65
Cul-2006	10.32	13.44	11.88	248.30	159.16	203.73	1.08	0.52	0.80
CIRJ-7	15.36	15.36	15.36	218.12	146.48	182.30	0.90	0.59	0.75
CIRJ-8	13.20	10.80	12.00	212.75	171.30	192.03	1.05	0.57	0.80
CIRJ-9	10.80	12.72	11.76	237.56	148.03	192.78	0.85	2.45	1.65
CIRJ-19	13.20	12.72	12.96	212.80	212.74	212.77	0.75	0.49	0.62
Mean	12.07	12.91		231.12	155.44		0.97	0.72	
Varieties									
F value	11.87*			14117.26**			15.72*		
SE	0.64			0.326			0.083		
CD	1.896			0.954			0.245		
Processing									
F value	4.26*			5261.80*			21.703*		
SE	0.28			0.146			0.037		
CD	0.848			0.427			0.109		
Variety x Processing									
F value	1.73*			134792.9**			15.75*		
SE	0.90			0.461			0.119		
CD	2.682			1.349			0.347		

*Significant at 5 % level
** Significant at 1 % level

processing method was also found to be significant with respect to phosphorus content.

There was significant difference in iron content of the rice varieties studied. Highest value of iron content was noticed in *CIRJ-9* (1.65 mg) and lowest in *Vyttila-4* (0.58 mg). Iron content of raw rice ranged between 0.80 mg – 1.60 mg and that of parboiled rice, it ranged between 0.36 mg to 2.45 mg (Table 12).

Statistical analysis revealed that there was significant difference among the rice varieties with respect to processing method. Mean value of raw rice was found to be 0.97 mg, while that of parboiled rice 0.72 mg. There was slight decrease in iron content of rice varieties due to processing. The results revealed that significant interaction was noticed between varieties and processing method.

Table 13 depicts the sodium and potassium content of the rice varieties.

Table 13. Sodium and potassium content of rice varieties / cultures, mg / 100 g

Varieties	Sodium			Potassium		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	4.00	6.05	5.02	419.50	219.50	319.56
Vyttila-4	1.50	2.75	2.12	433.50	395.50	414.50
Vyttila-5	0.95	2.20	1.57	346.50	221.50	284.00
Cul-1026	1.55	3.00	2.27	411.00	308.50	359.75
Cul-1734	2.50	7.05	4.77	395.00	956.50	675.75
Cul-2006	5.20	2.85	4.02	423.50	636.50	530.00
CIRJ-7	3.00	11.90	7.45	319.00	435.50	377.25
CIRJ-8	1.50	12.35	6.92	400.00	475.50	437.50
CIRJ-9	3.65	3.55	3.60	484.00	383.00	433.50
CIRJ-19	2.90	5.45	4.17	355.50	515.00	435.25
Mean	2.67	5.71		398.75	454.65	
Varieties						
F value		140.47*			54.07*	
SE		0.16			15.16	
CD		0.485			44.725	
Processing						
F value		851.71*			33.98*	
SE		0.07			6.78	
CD		0.217			20.001	
Variety x Processing						
F value		150.21*			54.60*	
SE		0.23			21.44	
CD		0.687			63.250	

* Significant at 5 % level

There was significant difference in sodium content of rice varieties. Sodium content of raw rice ranged between 0.95 mg – 5.20 mg, while that of parboiled rice, it was between 2.20 mg – 12.35 mg. The highest value for sodium content was observed in *CIRJ-7* (7.45 mg) and lowest in variety *Vyttila-5* (1.57 mg).

Parboiling significantly increases the sodium content of rice varieties. From Table 13, it was observed that the mean value for sodium content of parboiled rice was 5.71 mg, while that of raw rice, it was 2.67 mg. The interaction between variety and processing method was much significant, with respect to sodium content of rice varieties.

Potassium content of raw rice varieties ranges between 319.48 mg – 484.00 mg, while that of parboiled rice, it ranges between 219.50 mg – 956.50 mg. There was significant difference in potassium content of rice varieties. Highest value was observed in *Cul-1734* (675.75 mg) and lowest value in variety *Vyttila-5* (284.00 mg).

Data when analysed statistically revealed that parboiling significantly increases the potassium content of rice varieties. Mean values for potassium content of parboiled rice was 454.65 mg, while that of raw rice, it was 398.75 mg. The interaction between variety and processing method was also found to be significant with respect to potassium content.

4.3 ORGANOLEPTIC CHARACTERISTICS

Parameters like aroma, odour and taste are very important quality characteristics, which have to be evaluated by sensory perception (Kawale, 1997).

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

The scores obtained for the quality attributes, 'colour' and 'appearance' of the ten rice varieties are presented in Table 14.

Table 14. Colour and general appearance of the rice varieties / cultures, scores

Varieties	Colour			Appearance		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	2.80	2.90	2.85	2.50	3.00	2.75
Vyttila-4	2.60	2.80	2.70	2.60	2.60	2.60
Vyttila-5	2.90	2.60	2.75	2.70	2.70	2.70
Cul-1026	3.60	2.60	3.10	3.40	2.50	2.95
Cul-1734	2.90	3.70	3.30	2.90	3.70	3.30
Cul-2006	3.70	3.50	3.60	3.20	3.80	3.50
CIRJ-7	3.20	2.50	2.85	3.10	2.40	2.75
CIRJ-8	3.30	2.90	3.10	2.70	3.00	2.85
CIRJ-9	3.40	3.10	3.25	3.20	3.00	3.10
CIRJ-19	3.10	2.50	2.80	2.90	2.60	2.75
Mean	3.15	2.91		2.92	2.93	
Varieties						
F value	1.25*			1.55*		
SE	0.71			0.23		
CD	0.718			0.644		
Processing						
F value	2.14*			0.004*		
SE	0.32			0.28		
CD	0.321			0.288		
Variety x Processing						
F value	0.96*			1.42*		
SE	1.01			0.91		
CD	1.016			0.912		

* Significant at 5 % level

A significant difference was observed in the mean scores obtained for the quality attribute 'colour'. Among the ten rice varieties *Cul-2006* had obtained highest score (3.60) for colour, while the variety *Vyttila-4* has obtained the lowest score (2.70).

The colour preference was found to be significantly affected by parboiling process. In the present study, preferences were shown for the colour of raw rice samples, when compared to parboiled samples. Mean score obtained for colour of raw rice varieties was 3.15, and that of parboiled rice varieties was 2.91. There was not much significant difference for the interaction between variety and processing method with respect to attribute 'colour'.

A significant difference was observed in the mean scores obtained for different varieties of rice for the attribute 'appearance' (Table 14). Among the ten rice varieties, *Cul-2006* had obtained the highest score for appearance (3.50), while variety, *Vyttila-4* had obtained the lowest score (2.60).

There was not much significant difference in the mean scores obtained for each variety, for the quality attribute 'appearance' when processed by raw and parboiling methods. Mean score for raw rice was 2.92, while that of parboiled rice was recorded as 2.93. The interaction between the varieties and processing method was found not to be significant with respect to attribute 'appearance'.

'Flavour' and 'texture' of rice varieties / culture were presented in Table 15.

Table 15. Flavour and texture of rice varieties / cultures, scores

Varieties	Flavour			Texture		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	2.60	3.50	3.05	2.00	2.20	2.10
Vyttila-4	2.70	2.80	2.75	2.30	2.00	2.15
Vyttila-5	2.90	2.20	2.55	2.60	2.20	2.40
Cul-1026	2.80	2.70	2.75	2.30	2.60	2.45
Cul-1734	2.90	3.20	3.05	2.90	2.60	2.75
Cul-2006	2.80	3.50	3.15	3.00	3.10	3.05
CIRJ-7	2.70	2.60	2.65	3.30	2.40	2.85
CIRJ-8	3.10	2.90	3.00	2.20	2.50	2.35
CIRJ-9	2.60	2.90	2.75	3.20	2.60	2.90
CIRJ-19	2.70	2.70	2.70	2.40	2.10	2.25
Mean	2.78	2.90		2.62	2.43	
Varieties						
F value		0.97*			2.34*	
SE		0.20			0.22	
CD		0.571			0.609	
Processing						
F value		0.84*			1.86*	
SE		0.09			0.09	
CD		0.255			0.272	
Variety x Processing						
F value		1.23*			0.84*	
SE		0.29			0.31	
CD		0.808			0.862	

* Significant at 5 % level

There was a significant difference among the different rice varieties for the quality attribute 'flavour' as shown in Table 15. As in case of the attributes 'colour' and 'appearance', the highest score for flavour was also obtained for *Cul-2006* (3.15), and the lowest score for the variety *Vyttila-5* (2.55).

The flavour of the different rice varieties were found to have not much 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 2.90. The interaction between varieties and processing method was not significant with respect to attribute 'flavour'.

The texture of the rice varieties was also found to be the highest for *Cul-2006* (3.05), which was found to be on par with *CIRJ-9* (2.90). It was found to be the lowest in variety *Vyttila-2* (2.10), which was found to be on par with variety *Vyttila-4* (2.15). There was a significant difference among the different rice varieties with respect to quality attribute 'texture'.

Statistical data revealed that there was no significant difference among the ten rice varieties with respect to quality attribute 'texture' due to parboiling process. Mean scores obtained for 'texture' of the raw cooked rice was 2.62, while that of parboiled cooked rice was 2.43.

Details on quality attributes, 'taste' and 'overall acceptability' is depicted in Table 16.

Among the various quality attributes, taste is the primary one and of utmost important. Significant difference was noticed among the rice varieties for quality attribute 'taste' (Table 16). Among the ten rice varieties, highest score for taste was obtained for *Cul-2006* (3.25) and lowest for variety *Vyttila-4* (2.30).

No significant difference was observed with respect to the quality attribute 'taste' in the ten rice varieties due to parboiling process. In raw rice, mean score obtained for the quality attribute 'taste' was 2.87, and that of parboiled cooked rice was 2.70.

Table 16. Taste and overall acceptability of rice varieties / cultures, scores

Varieties	Taste			Overall acceptability		
	Raw	Parboiled	Mean	Raw	Parboiled	Mean
Vyttila-2	2.60	3.40	3.00	2.50	3.00	2.75
Vyttila-4	2.40	2.20	2.30	2.52	2.48	2.50
Vyttila-5	3.20	2.60	2.90	2.86	2.46	2.66
Cul-1026	3.00	2.30	2.65	3.02	2.54	2.78
Cul-1734	3.20	2.80	3.00	2.96	3.20	3.08
Cul-2006	3.10	3.40	3.25	3.16	3.46	3.31
CIRJ-7	3.00	2.80	2.90	3.06	2.54	2.80
CIRJ-8	2.60	2.70	2.65	2.78	2.80	2.79
CIRJ-9	2.80	2.60	2.70	3.04	2.84	2.94
CIRJ-19	2.80	2.20	2.50	2.78	2.42	2.60
Mean	2.87	2.70		2.86	2.77	
Varieties						
F value	1.68*			1.91*		
SE	0.21			0.17		
CD	0.592			0.475		
Processing						
F value	1.57*			0.75*		
SE	0.09			0.07		
CD	0.265			0.212		
Variety x Processing						
F value	1.17*			1.07*		
SE	0.30			0.24		
CD	0.838			0.672		

* Significant at 5 % level

The overall acceptability of different rice varieties were significantly different. *Cul-2006*, was found to be most acceptable rice with a maximum score of 3.31, followed by *Culture CIRJ-9* (2.94). The minimum score was obtained for variety *Vyttila-4* (2.50). There was no significant difference between the raw and parboiled rice varieties with respect to overall acceptability.

4.5 SELECTION OF SUPERIOR VARIETY

The superior variety was selected based on physical, cooking and nutritional qualities of rice varieties (Table 17).

Table 17. Selection of superior variety based on physical, cooking and nutritional qualities

Sl. No.	Varieties	Index score	
		Raw rice	Parboiled rice
1.	*Vyttila-2*	394.36 (1)	531.36 (1)
2.	*Vyttila-4*	333.00 (8)	378.90 (6)
3.	*Vyttila-5*	316.61 (10)	347.54 (9)
4.	*Cul-1026*	326.42 (9)	366.88 (8)
5.	*Cul-1734*	350.29 (5)	401.72 (3)
6.	*Cul-2006*	392.22 (2)	524.88 (2)
7.	*CIRJ-7*	354.18 (3)	391.76 (4)
8.	*CIRJ-8*	343.30 (6)	326.55 (10)
9.	*CIRJ-9*	350.31 (4)	388.49 (5)
10.	*CIRJ-19*	338.58 (7)	374.03 (7)

(Figures in paranthesis indicate rank order)

Variety *Vyttila-2* was found to be the superior variety of rice in both raw (394.36) and in parboiled (531.36) forms, followed by *Cul-2006* having scored 392.22 in raw form and 524.88 in parboiled form. The cultures *CIRJ-7*, *Cul-1734* and *CIRJ-9* assumed the next three ranks in both forms, with variation among themselves. Parboiling had favourably influenced the scores of *Cul-1734* compared to the other two cultures. Parboiling had similar negative effect on culture *CIRJ-8*. The culture *CIRJ-19* occupies seventh position in both the cases. In the case of varieties *Vyttila-4*, *Vyttila-5* and *Cul-1026*, there was a positive shift in the ranks with respect to parboiled samples.

DISCUSSION

5. DISCUSSION

This chapter encompasses a critical appraisal of the salient findings of the study "Quality analysis of *Pokkali* rice varieties/cultures" and the discussion is presented under

5.1 Physical characteristics

5.2 Cooking characteristics

5.3 Nutritional composition

5.4 Organoleptic qualities and

5.5 Selection of superior variety

5.1 PHYSICAL CHARACTERISTICS

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. All the ten rice varieties studied are classified into bold medium 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).

Colour when observed among ten varieties, two varieties and four cultures were found to have red colour and three cultures and one variety were white in colour. Rice is very sensitive for colour change. Parboiling, depending on the processing conditions, alters the colour of rice to varying extent. In the present study, parboiling process was found to change the colour in some varieties. According to Varadharaju *et al.* (2001), if the temperature is at 140^{0}C range, it would influence the change of colour in optimum parboiled samples. Similar results were also reported by Biswas and Juliano (1988).

Physical dimensions of 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. Length of the grain is measured in its greatest dimension, width along the ventral side and thickness across the dorsal side.

There was slight but apparent change in the length of milled rice due to parboiling. Parboiling significantly reduced the length of the rice varieties. This may be due to vertical shrinkage due to escape of moisture during parboiling. This result confirms with the earlier observation on parboiled rice by Das *et al.* (1983) and Sheena (1997). Bandhopadhayay and Roy (1992) had reported that parboiling and subsequent drying might cause a decrease in the length and an increase in the width of rough and brown rice.

But, in some varieties (*CIRJ-7*, *CIRJ-8* and *CIRJ-19*) it was noticeable that due to parboiling treatment, there was an increase in length instead of decrease in length. This may be because, the grain length is significantly influenced by the processing method irrespective of the size and shape of the grain. Sowbhagya and Ali (1991) opined that pre soaking causes an increase in the grain length by about 20 per cent, but a reduction in thickness by about five per cent, in firmness by about ten per cent, and in elasticity of the grain by about 25 per cent over unsoaked control. Sadhna *et al.* (1998) reported significant difference between raw and parboiled rice with respect to grain length and L/B ratio. The authors also reported 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. .

When observed the width of the rice varieties, it was found that there was significant difference between the varieties, as well as processing method applied. It was found that the width of the rice varieties decreased due to parboiling treatment. This may be because parboiled rice showed rounding of the peripheral contour and disappearance of the lateral ridges along the short axes, which makes the grain look roundish as compared to raw rice. Similar results were also observed by Sowbhagya *et al.* (1993). But in some varieties like *CIRJ-7, CIRJ-9* and *CIRJ-19*, there was an increase in width due to parboiling. White belly grains in general possessed higher breadth and weight, lower absolute density and equilibrium moisture content and exhibited higher susceptibility to crack formation than translucent grains. This findings is on par with the study reported by Bhashyam *et al.* (1985).

The L/B ratio is used in classifying the shape. Based on length / width ratio (FAO, 1970) rice grains are classified as slender long grain rice, bold medium grain rice and round short grain rice.

The L/B ratio varied significantly between the rice varieties. In the present study it was found that there was not much significant difference between the L/B ratio of ten rice varieties with respect to processing method, but it can be observed that there was slight decrease in L/B ratio of parboiled rice (2.31) when compared to raw rice (2.32). The result is on confirmation with study conducted by Kaur *et al.* (1991) and Sheena (1997). Traditional parboiling significantly decreased the L/B ratio of milled rice kernels than the control (Kaur *et al.*, 1991). But L/B ratio of some varieties (*Vyttila-4, Cul-1026, Cul-2006* and *CIRJ-8*) increased after parboiling. This may be due to the variation in the grain dimensions and shape of the varieties selected. This result is on confirmation with the study conducted by Sowbhaghya *et al.* (1993). The authors reported that the L/B ratio of parboiled rice (2.40) was higher, when compared to raw rice (2.28).

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

A significant difference in the thousand grain weight was observed among the rice varieties (Fig. 2). In the present study, it was observed that varietal variation had a profound influence on this variable. According to Webb and Sterner (1972) the thousand grain weight of rice varieties varied considerably with the moisture content in the grain. Therefore, 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. In earlier studies, it was reported that the grain harvested during the 'virippu' season (July–August) had higher volume and weight than the grains harvested during the 'mundakan' season (December–January) (Dev, 1991). From the study conducted by Saikia (1990), it was found that slender grains has lowest thousand kernel weight for paddy, brown and milled rice. Similar results were also reported by Bhattacharya and Ali (1972) and Sindhu *et al.* (1975).

The thousand grain weight was found to vary significantly after parboiling. Parboiled samples had significant 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. But contrary to this, in some varieties, there was slight decrease in thousand grain weight after parboiling. Usha *et al.* (1999) reported that extended milling of rice decreases the incidence of microflora and reduce the kernel weight and head rice yield of the rice varieties.

Head rice yield is the yield of milled rice obtained on milling of paddy. It is one of the most important criteria of rice quality especially from marketing standpoint. A variety should possess a high turn out of whole grain (head) rice and total milled rice (Dela and Khush, 2000).

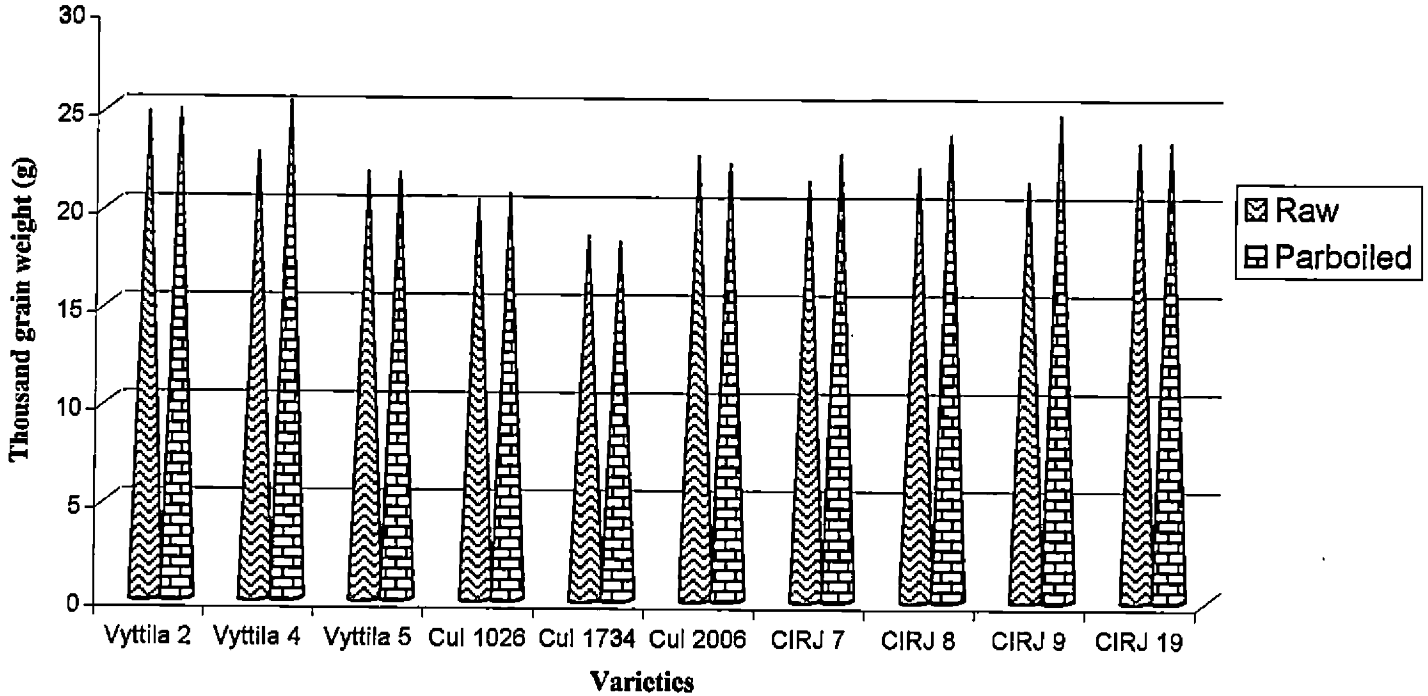

Fig. 2. Effect of parboiling on thousand grain weight of rice varieties/cultures

The head rice yield is sensitive to the mode of drying. The head rice yield may increase upto one per cent, if drying is postponed for a day in order for the internal moisture gradients in the kernels, and the different moisture contents between the individual kernels to equilibrate, but delaying the drying beyond 24 hours does not affect head yield. As reported by Bandyopadhyay and Roy (1992), paddy harvested at higher moisture content (21 – 24 % wet basis) and dried by a mechanical drier gives better yield of milled rice when compared to paddy dried in the sun.

In the present study, there was significant difference between the rice varieties with respect to head rice yield. Head rice yield of the parboiled rice samples were significantly higher (77.63 %), when compared to the raw rice samples (72.79 %) (Fig. 3). This may be due to the changes in the process of hardening of the endosperm of the grain. Similar observations were reported by Neelofer (1992), Nandini (1995) and Sheena (1997). A study by Vimala (1997) concluded that a pre treatment method of soaking during parboiling will increase the head rice yield. Daniels *et al.* (1998) stated that low temperature dried rice gives significantly greater head rice, yield cooking properties and peak viscosity than did high temperature dried rice. As reported by Imoudu and Oku Fayo (2000) it was noticed that parboiled rice dried on a concrete gave a higher yield percentage and lower proportion of broken grains than the grains dried on a mat.

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 (0.025 ml/seed) when compared to raw rice (0.010 ml/seed). Swelling index was also more for parboiled rice samples (1.16) than raw rice samples (0.44).

The water absorption capacity, as reflected by swelling ratio is significantly lower for parboiled rice than for raw rice cooked for same period. But, samples of raw rice and parboiled rice soaked to an

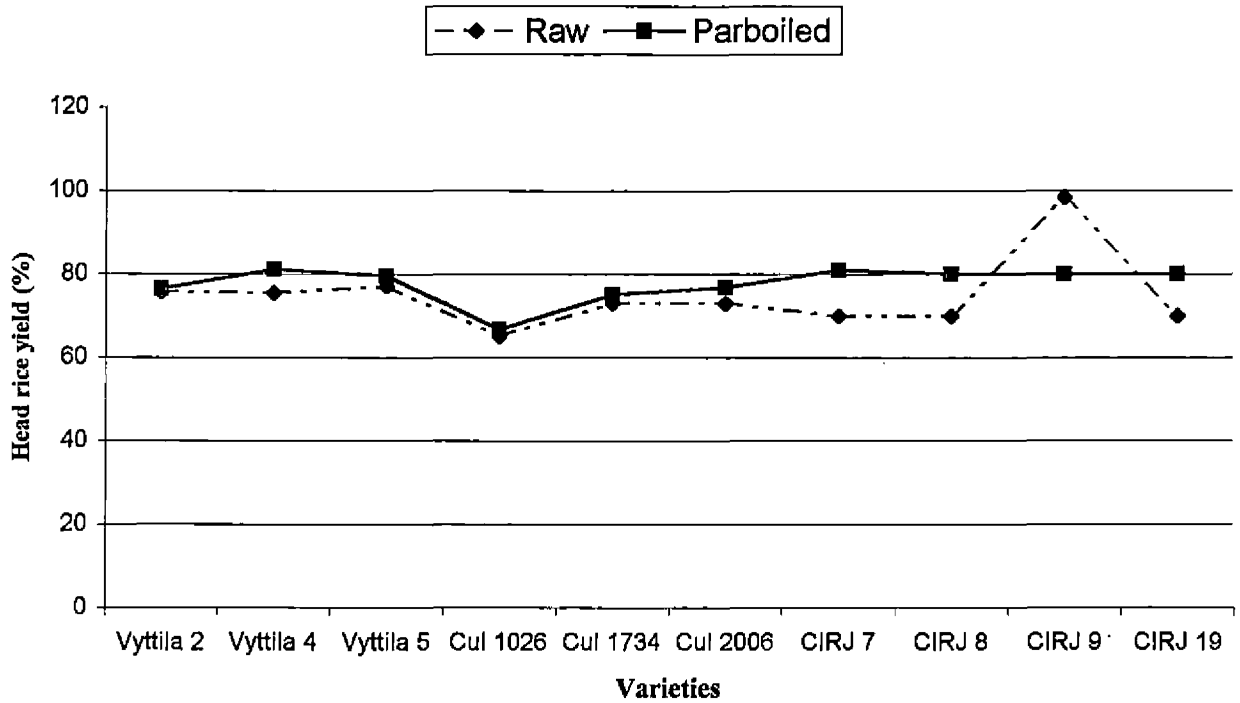

Fig. 3. Effect of parboiling on head rice yield of rice varieties/cultures

equivalent degree show that parboiled rice can absorb more water without losing its shape and raw rice cooked for 15 or 20 minutes had a lower swelling ratio than parboiled rice cooked for 30 or 40 minutes respectively (Araullo *et al.*, 1976). As reported by Sowbhagya *et al.* (1993) rice tends to become coarser by parboiling and these coarser varieties have higher porosity, therefore more swelling.

Begum and Bhattacharya (2000) reported that the nature and amount of non starch constituents are important factors which act as physical barrier 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.

5.2 COOKING CHARACTERISTICS

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

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 was found to significantly vary among the rice varieties. Parboiling process significantly increased the cooking time of rice varieties. The increase in the optimum cooking time after parboiling may be due to the variation in the rate of hydration and consequent gelatinization. Parboiled rice took 25.10 min. to cook, compared with 22.30 min. of raw milled rice. Sreedevi (1989), Nandini and Prema (1996) and Sheena (1997) have also reported similar observations.

But, while considering few varieties in particular (*Cul-1026, Cul-1734, Cul-2006* and *CIRJ-8*), it was observed that there was a decrease in cooking time after processing. This may be due to deterogradation of parboiled paddy, if the moisture is rapidly reduced followed by quick dissipation of heat. Similar results were also reported by Varadharaju *et al*. (2001). The decrease in the cooking time was also speculated by Sowbhagya and Ali (1991), and may be due to higher moisture content of pre soaked rice facilitating faster heat transfer. According to Usha *et al*. (1999) discoloured rice requires significantly less time to cook. The authors also reported that pre soaking causes a reduction in cooking time.

Begum and Bhattacharaya (2000) found that when more fat was available in raw rice, cooking time increases. Reverse phenomenon was observed in glutinous varieties, which consume more time as against low fat content.

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 (2.06 %) when compared to parboiled rice (1.38 %) (Fig. 4). Because starch in parboiled rice is already cooked or gelatinized. This study confirms with the findings of Rajalakshmi (1984), Sreedevi (1989), Nandini and Prema (1997) and Sheena (1997).

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

A significant increase in volume expansion was observed when rice varieties were parboiled. Volume expansion of parboiled rice was noted to be high (8.47), compared to raw rice (7.74). This may be due to loosened husk and other factors related to changes brought about during the parboiling operations. The findings are on line with that of

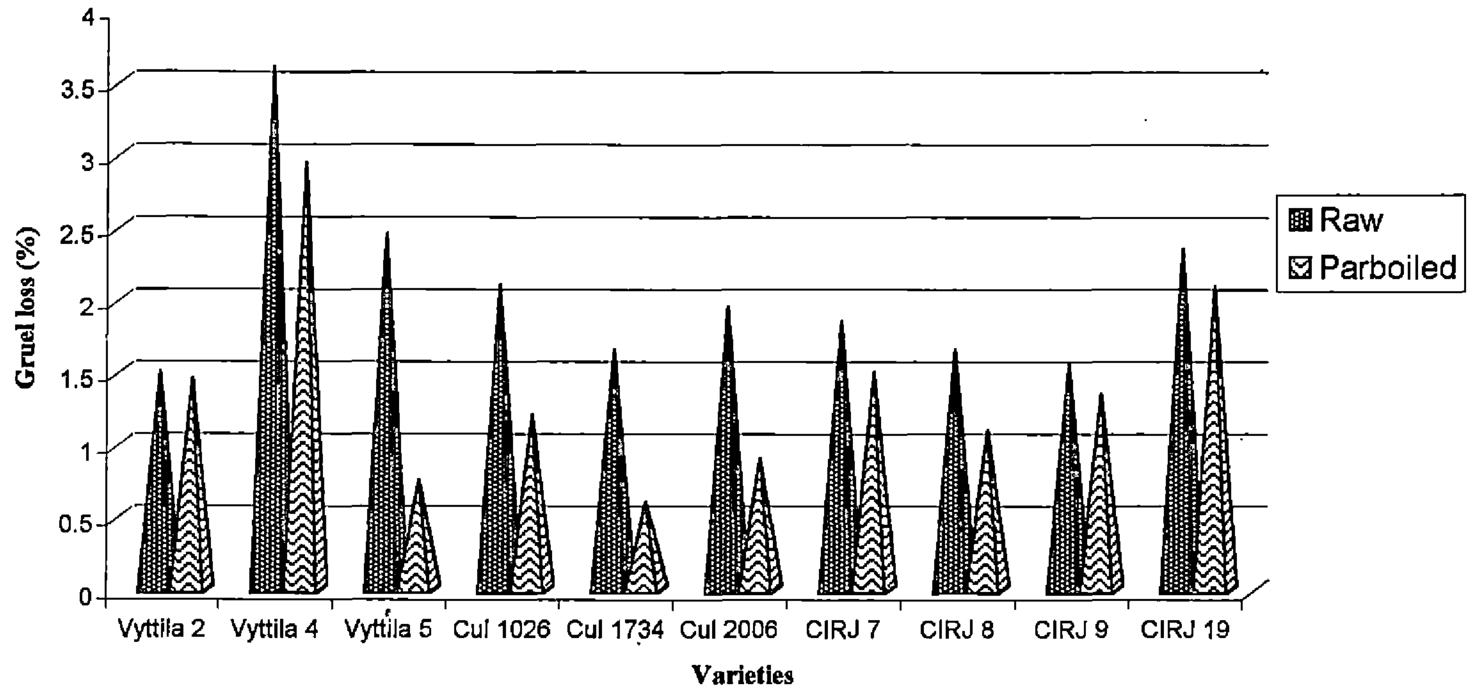

Fig. 4. Effect of parboiling on gruel loss of rice varieties/ cultures

Sheena (1997). But in some varieties (*Cul-2006, CIRJ-7, CIRJ-8, CIRJ-19*) volume expansion was decreased after processing. This can be explained from the findings of Kumari and Padmavathi (1991) who found that volume expansion was less for short grain varieties than long grain varieties and parboiling process decreases the length of the varieties. Usha *et al.* (1999) stated that discoloured rice reduces kernel elongation in cooked rice.

Water uptake is a measure of the hydration characteristics of rice which may be influenced by factors such as gelatinization temperature and porosity of the kernel (Bandhyopadyay and Roy, 1992). Higher water uptake is an indicator of better cooking quality of rice. Begum and Bhattácharya (2000) reported that when more fat was available in raw rice, water uptake decreases.

In the present study compared to raw rice varieties, parboiled rice had a significantly higher value for water uptake ratio. The mean value obtained for raw rice was 4.79 and that of parboiled rice was 5.34. 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), Nandini (1995),Sheena (1997) and Otebayo *et al.* (2001). In some varieties (*CIRJ-7, CIRJ-8, CIRJ-19*), the water uptake ratio was found to decrease as a result of parboiling treatment. This may be due to the fact that parboiled rice was hard due to gelatinization and resists absorption of water into it during cooking. Similar findings were observed by Patil *et al.* (1982) and Varadharaju *et al.* (2001).

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 crystallinity and birefringence. According to Dela and Khush (2000), gelatinization temperature of rice ranges from 55 to 79^0C.

Gelatinization temperature strongly influences the cooking quality of rice. Rice varieties with intermediate gelatinization temperature (70 -- 74^0C) are preferred all over the world, as the high gelatinization temperature rice becomes excessively under cooked, under standard cooking procedure and hence least preferred (Singh *et al.*, 2000). In the present study, all the rice varieties (both raw and parboiled) were found to be of intermediate gelatinization temperature type.

A slight significant lower gelatinization temperature was observed in parboiled rice samples (71.40^0C) when compared to raw rice samples (72.70^0C). In parboiling process, normally starch gelatinizes in the grain to ensure discrete rice kernels when cooked. A significant lower gelatinization temperature values of parboiled rice in the present study reveals that during parboiling process, the starch content of rice has not fully gelatinized. This may be due to environmental condition such as low heat applied during processing, as high ambient temperature results in starch with high gelatinization temperature. Contrary to the above results, in some of the cultures (*Cul-1026, CIRJ-9, CIRJ-19*), 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 Ali and Bhattacharya (1980a), Sreedevi (1989) Nandini (1995) and Sheena (1997).

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 1.30 in parboiled rice samples and 1.27 in raw rice samples. The increase in elongation ratio might be due to increased grain length brought about by parboiling of paddy. This result was in line with findings of Kaur *et al.* (1991) and Sheena (1997). The elongation ratio values in some of the cultures (*Cul-1734, Cul-2006, CIRJ-7, CIRJ-8* and *CIRJ-19*) was found to be lower after parboiling when compared to raw counterparts. This may be because temperature of parboiling influence the linear elongation of the rice kernel. These values are in confirmation with the study conducted by Sreedevi (1989).

Sowbhagya and Ali (1991) reported that elongation ratio increases marginally by about five per cent only, by pre soaking and cooking in long grain rice, eventhough they elongate more on direct cooking.

Elongation index is the ratio between the length and width of cooked grain and that of uncooked grain. It is related to grain dimension. The elongation index will give a measure of the percentage increase in the grain dimension after cooking.

In the present study, it was noticed that parboiling process significantly increased the elongation index of rice varieties. The mean value for elongation index of parboiled samples was 1.73, while that of raw rice samples was 1.64. The parboiled rice grains after cooking appear bigger and bolder than cooked raw rice. Similar trends were also observed by Sreedevi (1989), Nandini (1995) and Sheena (1997). Contrary to the above results, in some cultures (*Cul-1734, Cul-2006, CIRJ-7, CIRJ-8, CIRJ-9* and *CIRJ-19*), the elongation index was found to decrease when compared to raw milled varieties. This might be due to short and plump appearance of the grain.

5.3 NUTRITIONAL COMPOSITION

Majority of Indians are traditionally vegetarians by their dietary habits and derive most of their nutrient requirement from plant foods.

There is an ever-growing need for cereal grain to meet the energy and protein requirements.

Rice is a rich source of energy and moderate source of protein. Cereals are the main source of energy contributing 70–80 per cent of the daily energy needs. Rice provides more calories when compared to other cereals.

Nutritional quality of rice can be evaluated by determining energy, protein, starch amylose, amylose-amylopectin ratio, moisture, fibre calcium, phosphorus, iron, sodium, and potassium.

Results from the present study revealed that all the rice samples were found to have higher calorific values after parboiling (Fig. 5). The mean value of rice samples after parboiling was estimated to be 389 kcal while that of its raw counterparts was 349 kcal. During parboiling, the brown outer layers (scutellum and germ) adheres to the grain and most of the nutrients in it are driven into the interior of the grain. Similar findings were also reported earlier by Rajalakshmi (1984), Sreedevi (1989), Nandini (1995) and Sheena (1997).

Protein in rice, is considered to be of good quality, therefore rice is considered to be major source of dietary protein in Indian diets, even though per cent protein in it amounts less. Protein is the second most abundant constituent in rice. Total quantity and quality of protein present, determines the overall nutritional quality of the grain. Among cereal proteins, rice protein is the most nutritive because of its higher lysine content (Bandhopadhyay and Roy, 1992).

In a study conducted by Sheena (1997), protein content of rice was in the range, 8.83 to 10.15 g/100 g, but in the present study, there was a drastic difference in the protein content of the ten rice varieties which ranged from 4.23 to 12.03g / 100 g. The difference may be due to several factors. The variability in protein content of rice was mainly due to the environment in which it has grown. The protein content varied from plant to plant. The protein contents of rice varied much with cultural practices also. High solar radiation during grain development generally reduced protein content.

Chen *et al.* (1998a) stated that protein content decreases with increasing kernel thickness to 1.69 mm after which it remains constant. Usha *et al.* (1999) reported that protein content, ash, reducing sugars, non reducing sugars and free fatty acids increase with number of discoloured grains where as amylose content decreases with the same. 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 of most of the rice varieties. The increase in protein content may be due to parboiling process which forces the nutrients from the bran layer into the centre of the grain. The resulting rice is fluffy and separate and retains more nutrients than un-enriched regular milled white rice. The result was in confirmation with the report of Wimberley (1983). The study conducted by Sadhna *et al.* (1999) reported that parboiled rice was found to have higher protein and ash contents and lower free amino acids and free fatty acids compared to raw rice.

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.

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. Zheng *et al.* (2000) reported that as drying temperature increases, the fatty acid content of

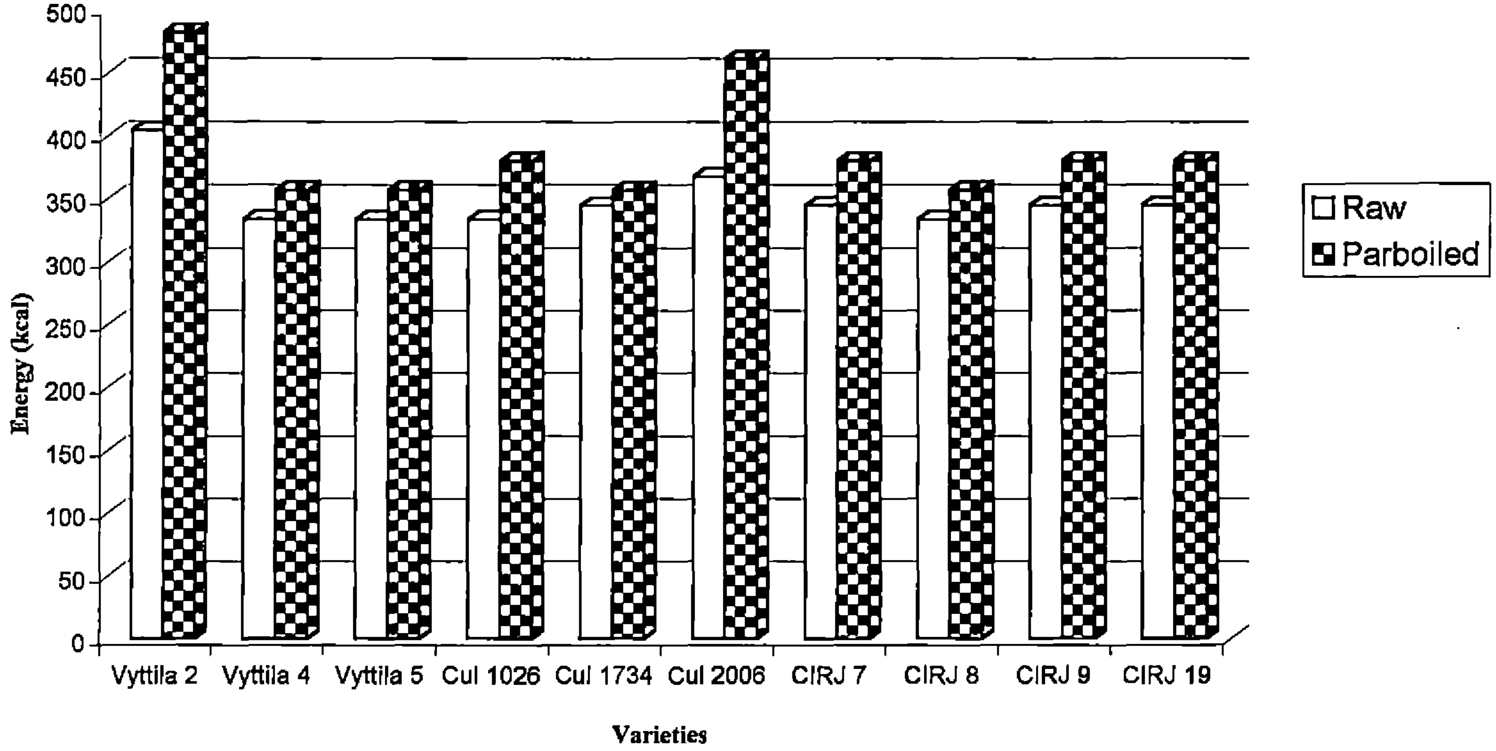

Fig. 5. Effect of parboiling on energy content of rice varieties/ cultures

grain increases resulting in more rapid rice ageing and prevents starch gelatinization. This lead to degradation of quality after drying.

It was noticed that the starch content of rice varieties reduced as a result of parboiling (Fig. 6). This may be due to the fact that during parboiling, starch granules are gelatinized and squeezed together, making the endosperm hard and compact. But, when each variety was analysed, it was observed that in most of the varieties, the starch content increased due to parboiling. Each variety may be constituting with different amylose-amylopectin ratio, which determines the textural properties of rice. The lower the percentage of amylopectin, the lower the water absorption capacity of the starch, the greater the temperature at which starch of the grain will gelatinize. Ali and Bhattacharya (1980a) had stated that the total starch content was unaltered in parboiling, but the soluble amylose content was increased depending upon the severity of parboiling. Similar findings were also reported by Kuzimina and Torzhinskaya (1973).

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, are glossy and sticky, and remain firm when cooked. High amylose content rice shows high volume expansion (not necessarily elongation) and a high degree of flakiness. They cook dry, are less tender and become hard upon cooling. Low amylose rice cook moist and are sticky. Intermediate amylose rice cook moist and tender and do not become hard upon cooling. Intermediate amylose rice are the preferred types in most of the rice growing areas of the world.

In the present study, amylose content varied significantly among the varieties. A significant decrease in amylose content was observed after parboiling. This may be due to the loss of gluten into

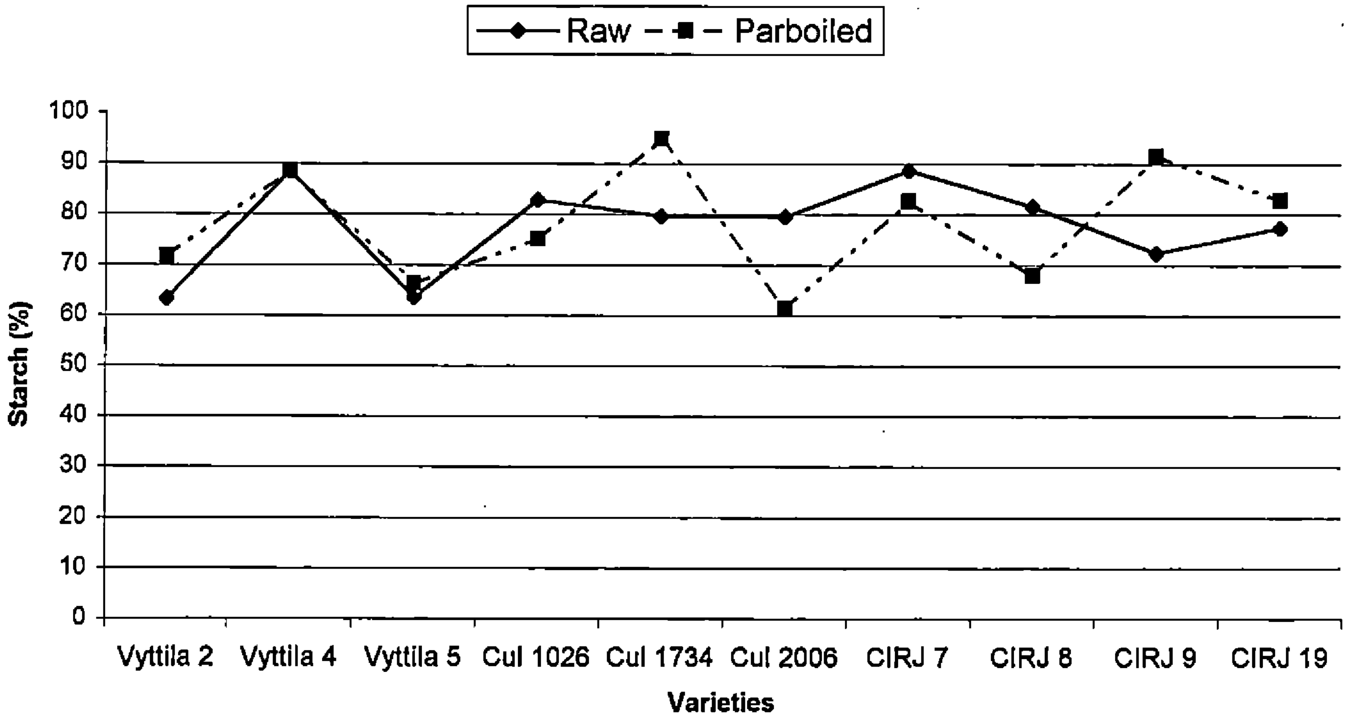

Fig. 6. Effect of parboiling on starch content of rice varieties / cultures

the gruel. Such negative effect of parboiling on amylose content was also reported by Sreedevi (1989), Nandini (1995) and Sheena (1997).

The ratio of amylose to amylopectin in starch has chief influence on eating quality. The amylose/amylopectin ratio is the major factor influencing water absorption and volume expansion during cooking, as well as the texture and gloss of boiled milled rice.

In the present study it was noticed that amylose and amylopectin ratio varied significantly among the rice varieties. But no significant difference was observed due to processing method applied among the ten rice varieties, and it was found that parboiling process slightly decreases the amylose-amylopectin ratio values (0.34), when compared to raw rice values (0.41). This may be due to variation in total starch and total amylose content.

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

According to Pillaiyar (1988), the extent of retro-gradation depend upon temperature of storage as well as the moisture content of parboiled paddy.

In the present study, a significant increase in moisture content was observed in parboiled rice samples (11.90 %) when compared to raw rice samples (11.24 %). 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 some varieties (*Vyttila-4* and *Cul-2006*). 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.* (1998b).

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.

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

In the present study, it was noticed that parboiling significantly influence the fibre content. As in the case of parboiled rice varieties, the same variety also showed the highest percentage of fibre content. This may be due to the fact that the nutrients from fibrous outer layers are forced into the centre of the grain during parboiling. Similar findings were also reported by Sheena (1997).

Generally, rice has 10 mg calcium per 100 g 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 ten varieties. It was noticed that parboiling significantly increased the calcium content of the rice varieties. Raw rice had lower content of calcium (12.07 mg / 100g), when compared to parboiled rice (12.91 mg / 100 g). This may be because due to parboiling process nutrient elements like calcium present in outer layers migrated deep into the grain, resulting in a greater retention in milled parboiled grain (Deosthale *et al.*, 1979). Also, as reported by Ocker *et al.* (1976) steaming increases the calcium content of the parboiled rice samples compared with that of raw milled rice. The increase was more noticeable if paddy samples are soaked for 18 hours; but soaking for 24 hours resulted in loss of calcium content of rice.

Contrary to the result, calcium content of few varieties (*Vyttila-5, CIRJ 8* and *CIRJ 19*), was found to decrease with application of parboiling technique. The loss in calcium content may be due to the reason that the calcium being dissolved out by the parboiled water. Sreedevi (1989) also reported loss of calcium due to parboiling.

The effect of parboiling on the phosphorus content of the rice samples when analysed, revealed that there was drastic decrease in phosphorus content of parboiled rice (155.44 mg / 100 g) when compared to raw rice counterparts (231.12 mg / 100 g). In variety *Vyttila-5*, it was found that phosphorus content increased after parboiling, contrary to the results of the rest of the varieties, where a drastic decrease in phosphorus content due to parboiling was observed. The present study revealed that iron content in parboiled rice samples decreased (0.72 mg / 100 g), when compared to that of raw rice varieties (0.97 mg / 100g). Iron content was found to be decreasing in most varieties, but surprisingly in cultures (*Cul-2006* and *CIRJ-9*), it was found to increase drastically after parboiling. This can be explained by the fact that severity of steaming in parboiling influences the mineral distribution in parboiled rice (Ocker *et al.*, 1976).

Results in the present study revealed that there was a drastic increase in sodium content. Mean value of parboiled rice samples was 5.71 mg / 100 g while that of raw rice samples was 2.67 mg / 100 g. Also, their is a drastic increase in potassium content of parboiled rice varieties (454.65 mg / 100 g), when compared to raw counterparts (398.75 mg / 100 g). This may be due to the fact that, parboiling process resulted in the transfer of natural vitamins and minerals from the rice bran layer into the starch endosperm. This confirms with the results of Doesthale *et al.* (1979) and Damir (1985).

5.4 ORGANOLEPTIC CHARACTERISTICS

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 a science that 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.

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, texture and taste. The attributes such as appearance, texture and flavour are final criteria of cooking quality and determine palatability or eating characteristics of cooked rice.

Colour is used as one criteria of quality of all rice varieties. The assessment is performed on whole milled rice. The colour of rice, also referred to as "general appearance", is influenced by such things as smut which imparts a gray colour or red rice seeds that gives the milled rice a rosy colour.

A significant difference was observed in the mean scores obtained for the quality attribute 'colour'. Parboiling process significantly affects the, 'colour' of rice varieties. In the present study, it was observed that preference for colour was shown for raw rice samples, when compared to parboiled samples (Fig. 7a). Lesser 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. Similar findings were also reported by Gariboldi (1974) and Sheena (1997).

The score obtained for 'colour' of raw rice was 3.15, compared to parboiled counterparts, 2.91. Contrary to this results, in few varieties (*Vyttila-2, Vyttila-4* and *Cul-1734*), parboiled rice samples scored more. This contradiction may be because Keralites mostly prefer parboiled rice.

General appearance is an important quality trait, because mostly rice is consumed in whole grain form. Numerous factors constitute general appearance including size and shape, uniformity, translucency, chalkiness, colour, damaged and imperfect grains.

In the present study, it was observed that there exists significant difference in the mean scores obtained for different varieties of rice, with respect to quality attribute 'appearance'. But it was also found that there was no significant difference between the rice varieties with respect to processing method *viz.*, parboiling for the attribute 'appearance' (Fig. 7a). The reason may be that all the rice varieties are categorized of bold and medium shape. Medium grain rices when cooked, are more moist and tender than long grain ones and also have a greater tendency to cling together.

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 were fluffy and less cohesive. Sreedevi (1989) also reported that parboiled rice score high value for appearance. But preference is given in the raw form in some varieties for the attribute 'appearance' (*Cul-1026, CIRJ-7, CIRJ-9* and *CIRJ-19*). This may be because the grain length was found to be correlated with palatability evaluation.

Flavour is one of the important criteria for selection of superior variety. In the present study it was revealed that there was significant difference among different rice varieties with respect to quality attribute 'flavour', and flavour of different rice varieties were found not to be significantly influenced by parboiling method (Fig. 7a).

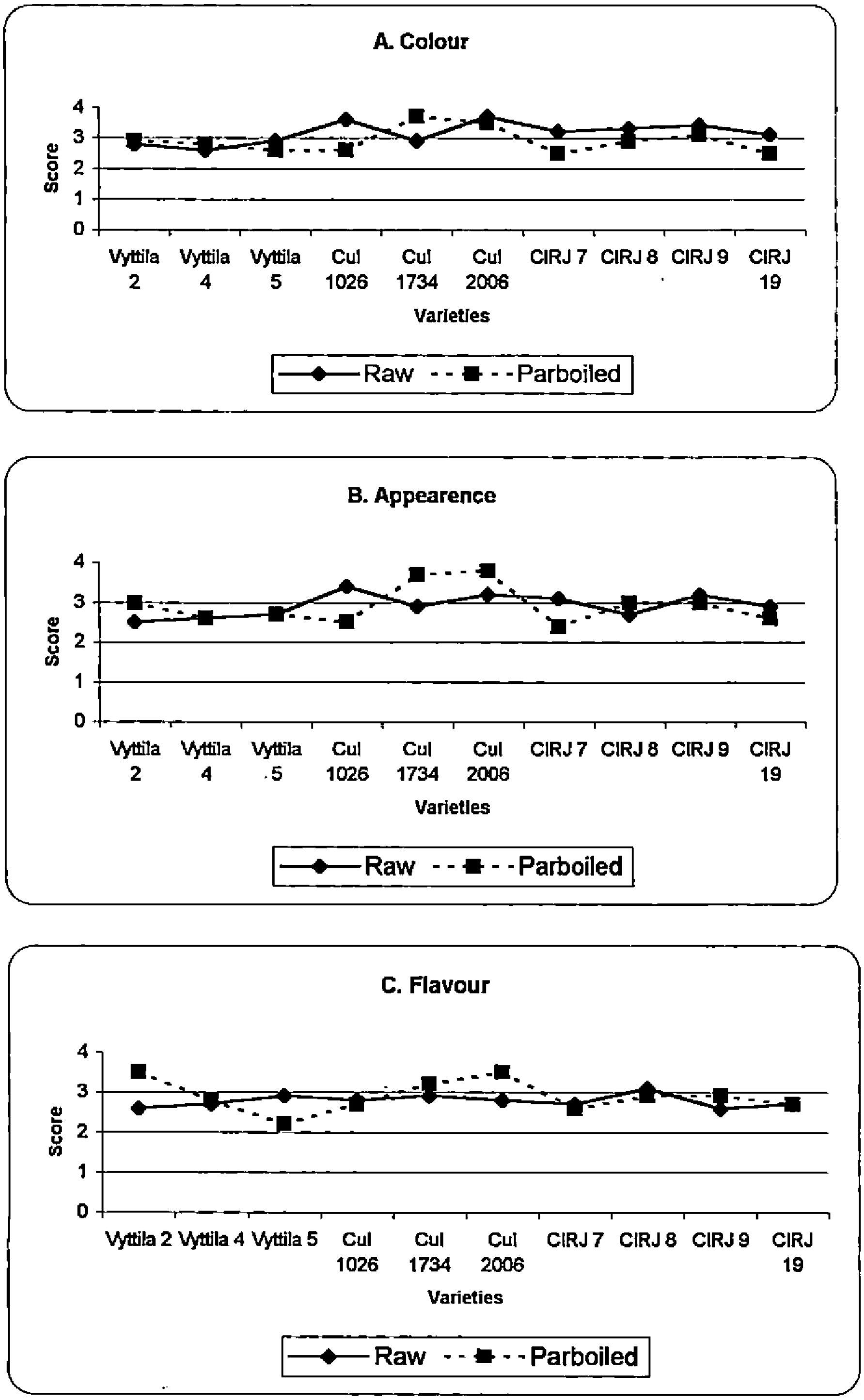

Fig. 7a Effect of parboiling on sensory evaluation of rice varieties / cultures

Flavour preference, in general, was found to be higher for parboiled varieties. Parboiled rice has a characteristic flavour compared to raw rice. This may be the reason for the increased acceptability of parboiled rice. According to Bandhyopadhyay and Roy (1992), the flavour of the parboiled product is the result of hydrolysis and decomposition of certain constituents such as proteins, under the influence of steam at high temperature during parboiling. They also reported that the secondary products responsible for the characteristic flavour are proteins consisting of "S" containing amino acids, which produce sulphurous compound (mercaptans) having a characteristic flavour and aroma.

Contrary to the above result, 'flavour' was preferred in raw form for varieties such as *Vyttila-5, Cul-1026, CIRJ-7* and *CIRJ-9* than in parboiled form.

Texture is another important quality criteria to be analysed. Parboiling changes the texture 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.

But result of the present study revealed that, there was a significant difference among the rice varieties for the quality attribute 'texture'. The mean score obtained for raw samples (2.62) was more when compared to parboiled samples (2.43) (Fig. 7b). In few varieties, textural preference was given for parboiled ones and in

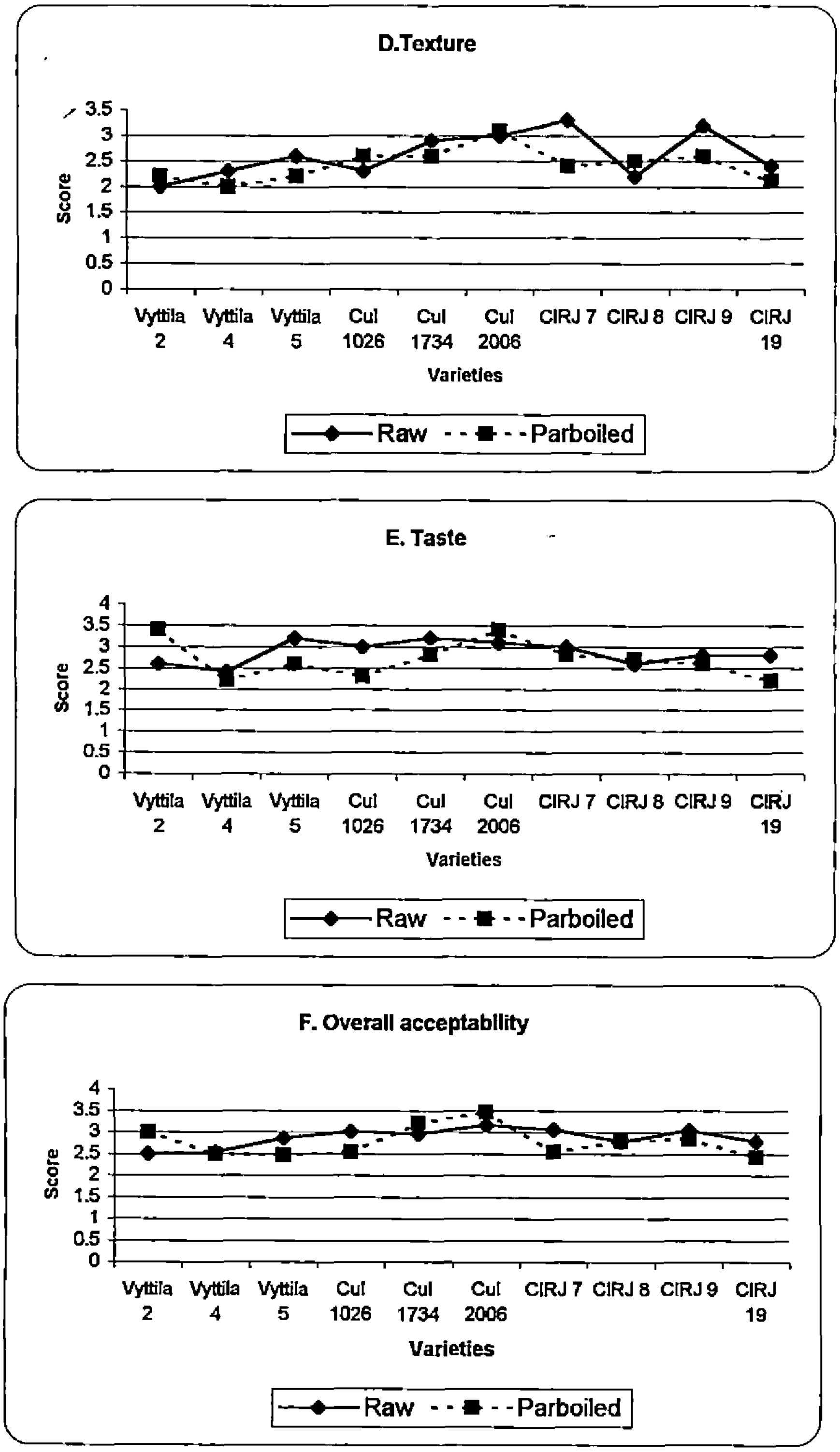

Fig. 7b. Effect of parboiling on sensory evaluation of rice varieties / cultures

some, for raw varieties. According to Juliano (1998) amylose content mainly determines the texture of cooked rice.

Among the various quality attributes 'taste' is of primary consumer interest for its marketability. Zheng and Zhao (2000) reported that drying temperature of paddy is the main factor affecting rice taste. After high drying temperature, rice fatty acid and amylose content increase and protein content was not noticeably changed. If the drying temperature exceeds 45^0C, the order of starch particle becomes mixed and disorderly.

In the present study, it was observed that there was significant difference in the mean score for the quality attribute 'taste' for different varieties, but there was no significant difference with respect to processing technology *viz.*, 'parboiling' applied (Fig. 7b). Parboiled rice had a characteristic taste and aroma, which is mostly accepted by Keralites compared with other States of India. But in the present study, it was found that raw rice samples scored slightly higher values (2.87), compared to parboiled samples (2.70). Open crack formation in polished rice during soaking results in damaged cooked rice and affects the taste of the cooked rice. The open crack formation increases with decreasing moisture content of polished rice and lower water temperature. Similar results were also reported by Koide *et al.* (2001).

The attribute 'taste' was preferred for varieties *Vyttila-2*, *Cul-2006* and *CIRJ- 8* in the parboiled form rather than in raw form.

The overall acceptability of different rice varieties was significantly different but, this aspect was not affected by the processing technique applied (Fig. 7b). This means that raw as well as parboiled rice was equally acceptable after cooking depending upon the mode of consumer preference and their food habits.

Okaodome *et al.* (1999) reported that with increasing nitrogen fertilizer application, the surface hardness increases and overall

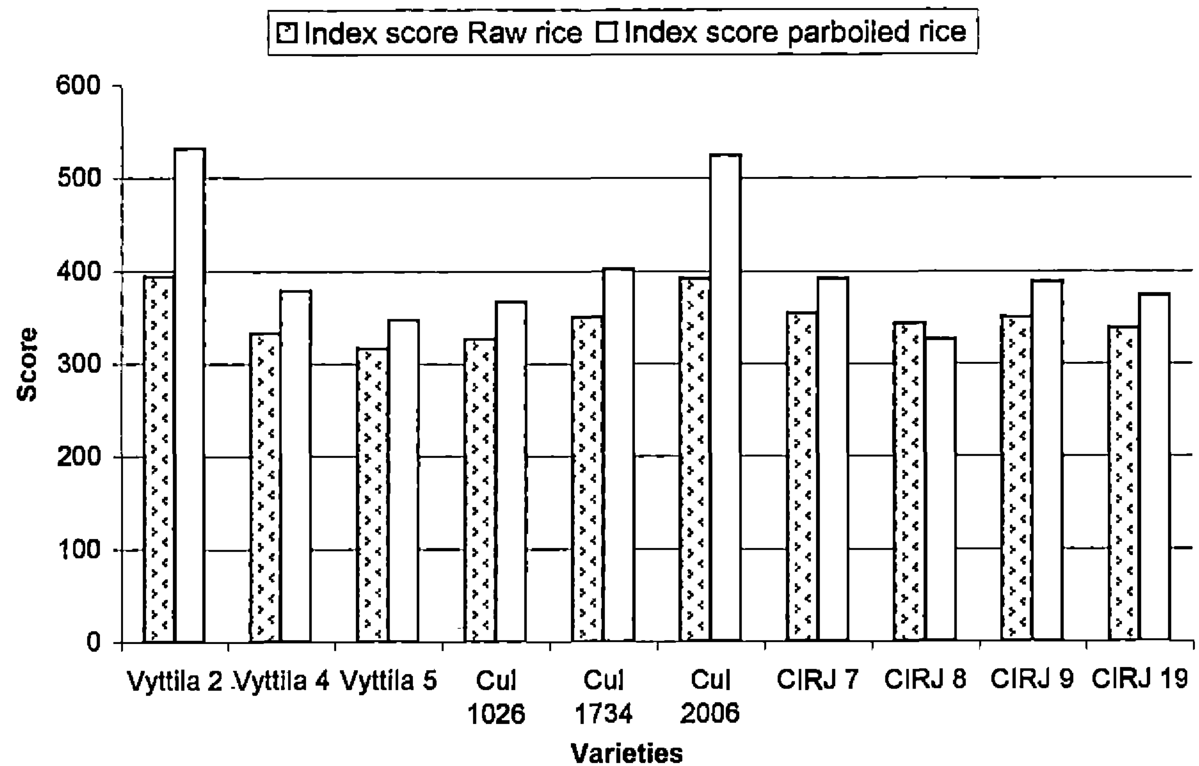

Fig. 8. Selection of superior variety based on physical, cooking and nutritional qualities

evaluation by sensory test decreased. Therefore physical properties of grain can discriminate the effects of nitrogen fertilizer on protein content and palatability.

As reported by Youngpei *et al.* (1999) there is significant positive correlation between albumin fraction of proteins and appearance, flavour, and overall acceptability of milled rice in the two varieties studied. A reverse relationship was found between storage proteins and eating qualities.

5.5 SELECTION OF SUPERIOR VARIETY

Variety *Vyttila-2* was found to be the superior variety in both raw and in parboiled forms, followed by *Cul-2006*. While considering palatability evaluations, it was found that *Cul-2006* was found to be the most acceptable compared to other varieties. Comparing the scores, it was observed that parboiling had favourably influenced few varieties and had shown negative effect on others. The reason can be explained because of the significant variation in the parameters of these varieties after parboiling (Fig. 8).

SUMMARY

6. SUMMARY

A study entitled "Quality analysis of *Pokkali* rice varieties / cultures" was conducted to assess the major quality parameters such as physical characteristics, cooking characteristics, nutritional composition and organoleptic characteristics; also the effect of parboiling on the above characteristics. Ten rice samples (three varieties and five cultures) were collected from Rice Research Station of Kerala Agricultural University, Vyttila 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, head rice yield, swelling capacity/ seed and swelling index.

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

Two varieties and four cultures *viz.*, *Vyttila-4*, *Vyttila-5*, *CIRJ-7*, *CIRJ-8*, *CIRJ-9* and *CIRJ-19* respectively were found to have red colour but cultures such as *Cul-1026*, *Cul-1734*, *Cul-2006* and variety *Vyttila-5* were 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 *Cul-2006*, and lowest in variety *Vyttila-5*. Parboiling significantly decreased the length and width of rice varieties, and the width was found to be the highest in variety *Vyttila-4* and lowest for *Cul-1026*.

Statistical analysis revealed that there was no significant difference between L/B ratio of the rice varieties due to parboiling process. L/B ratio was highest for *Cul-1026* and lowest for the variety *Vyttila-2*.

Thousand grain weight was recorded the highest for variety *Vyttila-2*. Parboiled samples had significant higher thousand grain weight values compared to raw rice samples.

The highest percentage of head rice yield was observed for *Cul CIRJ-9* and the lowest for *Cul-1026*. Parboiled rice samples had significantly higher head rice yield when compared to their raw counter parts.

Values for swelling capacity / seed were found to be the highest for *CIRJ-19*. 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 *Cul-1734* and there was a significant increase in swelling index as a result of parboiling.

The cooking characters studied were optimum cooking time, gruel loss, volume expansion, water uptake ratio, gelatinization temperature, elongation ratio and elongation index.

The optimum cooking time of the rice varieties increased when the rice samples were parboiled. *Cul-2006* took lesser time to cook, while variety *Vyttila-2* took maximum time to cook.

More gruel loss was experienced from raw rice when compared to parboiled counterparts. Nutritionally superior varieties are those which experience the least gruel loss. *Cul-1734* was recorded to experience the least gruel loss in the present study.

Higher volume expansion was observed in *Cul-2006* followed by *CIRJ-8*. A significant increase in volume expansion was observed, when rice varieties were parboiled.

Among the ten rice varieties studied, water uptake was found to be the highest for *Cul-1734* and lowest in *CIRJ-9*. There was no significant difference between the raw and parboiled rice, but it was noticeable that parboiled rice of same varieties had higher value for water absorption.

Highest value for gelatinization temperature was observed in variety *Vyttila-5* and a significant higher gelatinization temperature was noticed in raw samples compared to parboiled rice samples.

Lengthwise elongation was considered to be a desirable character, and among the ten varieties studied highest elongation ratio was possessed by *CIRJ-7*. Parboiling process significantly increased the elongation ratio of the rice varieties.

Elongation index was observed to be the highest in *CIRJ-7*. There was a significant increase in the elongation index as a result of parboiling.

Nutritional composition of the rice varieties were assessed by estimating calorific value, protein, starch, amylose, amylose-amylopectin ratio, moisture, fibre, calcium, phosphorus, iron, sodium and potassium.

Among the ten rice varieties studied *Vyttila-2* was found to have the highest calorific value followed by *Cul-2006*. It was found that parboiling process positively influences the calorific value of rice varieties.

Protein content was observed to be the highest in *CIRJ-8* and it was noticed that as a result of parboiling process, there was increase in protein content of the rice varieties.

Parboiling process reduced the percentage of starch content in rice varieties and highest value of starch content was recorded in the variety *Vyttila-4*.

Consumers prefer rice with intermediate amylose content and in the present study. *Vyttila-2, Cul-1734, Cul-2006, CIRJ-7, CIRJ-8* and *CIRJ-19* were grouped under intermediate amylose group.

A significant decrease in amylose content was observed after parboiling. The highest amylose content was noticed in *Cul-2006*, which was on par with variety *Vyttila-2*.

Amylose-amylopectin ratio varied significantly among the rice varieties and there was a slight but significant decrease in amylose-amylopectin ratio. It was recorded highest in variety *Vyttila-2*, which was on par with *Cul-2006*.

Moisture content was recorded to be lowest in variety *Vyttila-4* and a significant increase in the moisture content was observed in parboiled rice samples when compared to raw counterparts.

There was a slight but significant difference between the raw and parboiled rice varieties with respect to fibre content. Parboiling significantly increased the fibre content.

The *Cul-1026* was observed to have the highest value for calcium content, *Cul-1734* for phosphorus and potassium contents, *CIRJ-9* for iron content and *CIRJ-7* for sodium content respectively. Parboiling process showed a positive effect on concentration of some minerals like calcium, sodium and potassium contents and negative effect on phosphorus and iron contents respectively.

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

Statistical analysis revealed that eventhough parboiled rice samples obtained the highest scores for the quality attributes such as 'appearance' and 'flavour', compared to their raw counter parts, but, no significant difference was recorded due to the processing method applied. Contrary to this results, quality attributes 'colour', 'texture' and 'taste' were scored maximum for raw rice samples. There was no significant difference between the varieties with respect to overall acceptability. *Cul-2006* was found to be the most acceptable rice in both raw and parboiled forms as far as sensory evaluation by tested taste panels view was concerned.

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* Originals not seen

QUALITY ANALYSIS OF POKKALI RICE VARIETIES / CULTURES

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8. ABSTRACT

"Quality analysis of *Pokkali* rice varieties / cultures" was a study undertaken to determine the quality aspects of the above said rice varieties by assessing parameters like physical characteristics, cooking characteristics, nutritional composition and organoleptic qualities. The effect of parboiling on the above mentioned parameters were also studied.

As far as physical characteristics was concerned highest value for thousand grain weight was recorded in variety *Vyttila-2*, and for head rice yield, *CIRJ-9*. Parboiling significantly increased the thousand grain weight, head rice yield, swelling capacity / seed and swelling index values, while L/B ratio decreased as a result of parboiling.

When parameter, cooking characteristic, was taken into consideration, *Cul-2006* and *Cul-1734* were observed to record the least values for optimum cooking time and gruel loss which are generally considered as positive and desirable characters. Higher values for volume expansion was observed in *Cul-2006*; for water uptake, *Cul-1734* for gelatinization temperature, *Vyttila-5* and *CIRJ-7* for elongation ratio and elongation index 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, *Vyttila-2* had obtained higher values for nutritional characteristics such as calorific value, amylose-amylopectin ratio. *Vyttila-4* had highest starch content and lowest moisture content. *CIRJ-8* had recorded highest value for protein content. The *Cul-1026* was observed to have highest value for calcium content; *Cul-1734* for phosphorus and potassium content, *CIRJ-9* for iron content and *CIRJ-7* for sodium content respectively. Parboiling process positively influenced the nutritional composition of the rice varieties, exceptional

cases being starch, amylose- amylopectin ratio, phosphorus and iron contents.

Organoleptic evaluation of cooked rice, revealed that *Cul-2006* scored the highest and therefore can be considered as the most acceptable variety with respect to the given quality attributes such as colour, appearance, flavour, texture and taste.

To conclude, from the discriminant function analysis, it was found that *Vyttila-2* was considered best among the varieties studied, next being *Cul-2006*.

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 score	Code number of samples									
		1	2	3	4	5	6	7	8	9	10
Colour	5										
Appearance	5										
Flavour	5										
Texture	5										
Taste	5										
Total	25										

Comments

Number of panel members selected : 10

Number of replications : 2

(Signature)