A MULTI VARIATE APPROACH TO DEFINE THE QUALITY OF RICE

BY

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DECLARATION

I hereby declare that this thesis entitled "A multi variate approach to define the quality of rice", is a bonafide record of research work done by me during the course of research and that the thesis had 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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INTRODUCTION

INTRODUCTION

Rice is the most important cereal raised in tropical and subtropical regions of the world. Besides being the main source of energy for more than two - thirds of Indian population, it is the important staple because of its high digestibility, biological value and protein efficiency ratio among all the cereals (Sood, 1989).

Rice is the most important food crop of Kerala presently being cultivated in an area of 5.38 lakh ha. with an annual production of 10.85 lakh tonnes (Farm Guide, 1995). Rice is the staple food of Keralites from ancient time. Eventhough a number of varieties are advocated for cultivation, only selected varieties become popular and establish among farmers as well as end users, mainly due to their quality characteristics.

During the years of the high yielding variety programme and in subsequent years, stress had been given only towards higher yield and greater tolerance to pest and disease and not on the quality of the rice grains. However, the popularity and stability of such varieties in the market were ultimately influenced by their quality. The varieties with higher yield as the major characteristics are generally sold at a slight discount in the market compared to popular traditional varieties.

Though, prior to release, quality studies on rice grains are currently being conducted, want of a suitable index restricts quality studies at the screening stage itself. Earlier studies conducted in several institutions, on quality parameters of rice grains had identified more than 50 indicators which may influence the quality of rice grains. All these indicators may not equally contribute towards rice quality. A few selected indicators may contribute significantly towards a viable index. Such a comprehensive index covering all the important aspects needs to be developed in a systematic study for use both by breeders as well as by consumers. Such a study is very much required in the popular varieties in Kerala.

Further, the quality of various varieties for being used in different traditional preparations has to be systematically assessed and incorporated into indices to measure the quality needs as earlier pointed out. The present study is thus a relative assessment of major quality parameters of pre-released and released rice varieties popular in Kerala

State and the development of various indices which will be beneficial to the breeders as well as to the consumers of the State. The various aspects investigated are:

1. the physical characteristics of rice varieties selected
2. their cooking caracteristics
3. the effect of parboiling on the above quality parameters
4. the effect of different methods of cooking on the quality parameters and suitability of rice varieties for common rice based preparations popular in Kerala.
5. genetic divergence in raw and parboiled rice varieties based on organoleptic qualities.
6. nutritional composition and effect of parboiling on selected rice varieties
7. development of quality index for physical characteristics, cooking characteristics and organoleptic qualities for all the rice varieties selected
8. acceptability index based on the above mentioned quality parameters of various rice based preparations for all the rice varieties selected and
9. acceptability index based on physical, cooking, nutritional and organoleptic qualities for selected rice varieties.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

An investigation was carried out at the College of Agriculture, Vellayani to assess the quality of rice grain using different parameters like physical,nutritional, cooking and organoleptic, and also for developing a comprehensive index to determine the quality of rice grain. The study was conducted during the period from 1992 to 1994 using released varieties and pre-release cultures grown in different locations and used for preparation of various dietary items used for human consumption in Kerala. The relevant literature available on the above topics pertaining to rice are reviewed in this chapter.

Rice is the only major cereal in the world consumed commonly as a cooked kernel and it is the chief source of carbohydrates (Govindaswamy, 1985). According to Juliano (1990) rice provides 68 per cent of the total energy and 69 per cent of the total dietary protein in South Asia. Its importance as a food crop increases along with the increase in human population. To Indians, it is the most important food crop supplying, on an average, one third of the calories required (Saikia, 1990). Rice as the staple food of Keralites from ancient times has many diverse uses and is consumed in many forms (Mundy *et al.*, 1989).

The harvested rice grain is treated with various processing techniques before it reaches the consumer. As such the first operation at least in many areas in India is parboiling by which rice grain is partially cooked with intact husk. (Borasio and Gariboldi, 1965). According to Subramanyan (1971) parboiling of paddy is a premilling process originated in India and has been practised from time immemorial. As stated by Sikka *et al.* (1993) parboiling process consists of giving a hydrothermic treatment to the threshed paddy which is soaked in water, steamed for a short period, and dried to bring moisture back to an optimum level for milling and storing. Gariboldi (1974) had stated that parboiling process is to produce physical, chemical and organoleptic modifications in the rice with economic and nutritional advantage. He had also reported that 25 per cent of paddy produced in the world was parboiled.

Various methods of parboiling processes exist that differ from one another in the manner of hydration and heat treatment to gelatinize the starch. Parboiling process and techniques vary according to the requirements, needs, urgency and facilities available for processing. Parboiling is accomplished by soaking in hot (Central Food Technological Research Institute, 1960) water, cold water (Pillaiyar, 1977), open (Central Food Technological Research Institute, 1960) and closed heating [Pillaiyar *et al.*, 1977; Pillaiyar and Mohandoss (1981b)] or merely soaking at 70°C or 89°C (Ali and Ojha, 1976). Narunnabi *et al.* (1975) had standardized 2 methods of parboiling samples soaked at room temperature for 18 hours with variation in steaming time and atmospheric pressure applied. Among the cold, warm and hot soaking methods, cold soaking method had the least colour inducing effect while hot soaking had the most colour inducing effect on rice. The second method consists of boiling for 30 minutes without application of pressure and at a lower temperature.

The degree and intensity of heat treatment during each step of parboiling process greatly influence the nature and extent of changes in the end product. Besides the above variables, the retention time of hot paddy and the manner of drying influence the cooking and palatability characteristics of parboiled rice.

Kuppuswamy and Ramalingam (1978) had developed a new method of parboiling involving the hydration of the paddy by passing saturated hot air instead of soaking in liquid water. Raj *et al.* (1981) had improved the conventional parboiling of rice through prevention of husk opening by application of 0.5 to 1 per cent of common salt. This ensures husk sealed grains in parboiling. The improved method standardized by Raj *et al.* gave a better appearance to milled rice. He had also found that his new method of parboiling which produced husk sealed grains facilitated quick drying. He had also stated that the husk sealed grains remain free from fungal growth when drying was slow. The major advantage of this method was minimum loss of nutrients through the boiling water. Unnikrishnan *et al.* (1982) described an improved method for parboiling of paddy by simple soaking in hot water which gave a reasonably good parboiled rice with an acceptable colour.

In the process of removing the husks from paddy, force has to be applied. More force is required during removal of various layers which make up the bran polishings. Milling of rice and factors influencing it are important technological considerations in the processing of rice for the market. More than the type of mill, the pre-milling conditions mostly determine the milling quality. Different ethnic groups prefer various textures of cooked rice and the cooking and eating characteristics of rice are mostly determined by its composition (Pillaiyar, 1979). The main aspects of rice quality are the size and shape of grains, appearance, hulling and milling, cooking quality, nutritional composition and other special qualities which include the linear expansion of kernels on cooking (Govindaswamy, 1985).

Song (1986) reported that rice quality is determined by four major indices viz., milling quality, grain appearance, cooking and eating quality According to Pillaiyar (1988) rice grains are reported to become popular if they are attractive, whole and free from dirt, grit, obnoxious smell and toxic and deleterious residues. Bruce et al. (1991) opined that cooking, eating and processing qualities such as stickiness, firmness, integrity, flavour and appearance are the qualities required for marketing rice. According to Rosamma *et al.* (1991) two other important characters very specific to Kerala farmers are grain shape and kernel colour. The major quality aspects of rice grains are the physical characteristics, nutritional composition, cooking and organoleptic qualities.

2.1 PHYSICAL CHARACTERISTICS

Physical characteristics of the grains are found to be the major determinant of quality, which are decided by factors like thousand grain weight, grain dimension, moisture percentage, head rice yield and length-breadth ratio.

2.1.1 Thousand grain weight

According to Webb and Stermer (1972) the thousand grain weight of rice varieties varied considerably with the moisture content in the grain. The thousand grain weight of rice varieties varied considerably with the moisture content and farmers preferred grain with higher thousand grain weight.

The density and thousand grain weight of coarse varieties were higher than those of fine and medium fine varieties (Sindhu *et al.*, 1975). But Das *et al.* (1983) had reported that there exists a close relationship between grain weight and grain dimensions which are the important physical characteristics that influence the quality. In a study conducted by Lee *et al.* (1989) the thousand grain weight of paddy, brown rice and milled rice were not significantly different between tongil and japonica types.

Recent studies conducted by Ali *et al.* (1992) had found that split application of nitrogen fertilizer produced significantly higher thousand grain weight.

Raghavendra Rao and Juliano (1970) had stated that parboiling did not alter the thousand kernel weight.

Parboiling resulted in the harder texture of the endosperm and improved head rice yields (Raghavendra Rao and Juliano, 1970; Kimura *et al.*, 1976; Priestley, 1976a; Patil *et al.*, 1982) and low powdering values (Raghavendra Rao and Juliano,1970; Pillaiyar and Mohandoss, 1981b).

2.1.2. Grain dimension

The relationship between grain weight and grain dimension in determining the physical characteristics and thereby influencing the quality was studied by Das et al. (1983)

Soubhagya *et al.* (1984) had stated that certain indices deciding dimensional classification of rice such as normalized grain weight, grain weight per unit breadth; length and grain breadth are the indicators deciding the quality. Webb *et al.* (1986) had also found significant relationship between kernel length, kernel width and length - width ratio in rice grains.

2.1.3. Length - breadth ratio

Bandyopadhyay and Roy (1992) had stated that physical dimensions of length, breadth or width and thickness as well as shape of the kernels vary according to the variety and are considered as most important criteria of rice quality in developing new varieties for commercial production. The L/B ratio is also used in classifying the shape. Mahadevappa and Desikachar (1968) reported that expansion in length, breadth and lateral thickness are important quality parameters.

The L/B ratio of Moncompu varieties worked by Bai *et al.* (1991) ranged from 1.95 to 2.82.

According to Quadrat-i-kuda *et al.* (1962) parboiling had the effect of reducing the length and increasing the dorsi - ventral diameter in both rough and brown rice. Raghavendra Rao and Juliano (1970) had also noted the above changes in some varieties whereas in some others the original dimension was retained.

Bandyopadhyay and Roy (1992) had reported that parboiling and subsequent drying may cause a decrease in the length and an increase in the width of rough and brown rice.

2.1.4. Moisture content

According to Bandyopadhyay and Roy (1992) moisture content of rice is a very important factor which markedly affects several facets of rice quality: (1) to decide whether the grain should be dried before storage or shipment (ii) for controlling the rate of deterioration of the grain during storage (iii) for grading under ISI specifications (iv) for controlling milling quality during drying and storage (v) for controlling other quality factors associated with milling, cooking and processing characteristics (vi) for controlling the quality of rice to be used in dry breakfast cereals, parboiling and other processed rice and rice containing foods. Moisture content commonly accepted for safe storage period of rough rice are 12 per cent on wet basis for one year and 14 per cent for 3 to 6 months.

Studies conducted by Opakodum and Ikeorah (1981) had shown that moisture content of 34 samples of each of locally produced and imported rice was 6.34 to 15.13 per cent and 6.68 to 12.27 per cent respectively. According to Tomar (1981) moisture content was of great importance and paddy must be dried to about 14 per cent moisture level to avoid losses due to breakage in milling. Luh (1980) had reported a slight decrease in moisture content after parboiling. Huang (1986) had reported that moisture absorption by dry rice caused rice cracking that greatly influenced the milling quality.

2.1.5. Head rice yield

Rajalakshmi (1984) had reported that head rice yield is the percentage yield of whole milled rice obtained on milling of paddy. The percentage of broken rice was influenced by the nature and texture of the endosperm. The small grains (either fine or bold) have, in general, a higher recovery percentage than medium or long grains (Anon., 1961). Sidhu *et al.* (1975) had stated that coarse variety *IR-8* gave the higher yield of brown rice (83 per cent) . According the Esmay *et al.* (1979) milling operation produce the maximum yield of edible rice, obtain the best possible quality, minimize losses and minimize the processing cost. Sharma and Bains (1979) had observed high variability in head rice yield, refraction and broken rice within and between varieties. They have also found higher breakage in *Jaya* and *IR-8* when compared with *Basmati* 370 and *Palman* 579 varieties. Unnikrishnan *et al.* (1982) found that soaking paddy at a temperature of 10-15°C above the gelatinization point for 1 to 2 hours followed by draining out and hot tempering for another 1-2 hours gave parboiled rice with acceptable degree of parboiling, good milling and low breakage. Ali and Bhattacharya (1984) had found that the head rice recovery increased with increase in moisture content, pressure and time of steaming. Goodman and Rao (1985) and Anon. (1961) reported that long grain samples of rice gave significantly lower yields of head rice than short or medium grain samples. They also indicated that there exists a positive correlation between the kernel hardness and head rice yield. Lee (1986) had stated that the recovery rate of milled rice obtainable from paddy varied from 60-70 per cent according to the type of the mill, milling efficiency and the variety of rice.

Aguerre *et al.* (1986) had reported that the degree of breakage during milling increased as temperature of drying increased (from 40°C - 70°C) and relative humidity decreased during the process of parboiling.

Cuevas-Perez and Hosein (1987) had opined that cycles of high and low moisture can increase the proportion of broken grains during milling. He also found that rain can cause harvest delays and losses in rice milling quality.

In a study conducted by Banaszek and Siebenmorgen (1990) an empirical rate equation was developed to predict head rice yield for rough rice exposed to moisture absorptive conditions. They also reported that time of exposure, initial moisture content and relative humidity were reported to significantly reduce the head rice yield due to higher moisture absorption and further a decrease in head rice yield (more than 20 per cent point) was found in the lowest initial moisture content of rice samples (9 per cent wet basis).

According to Ali *et al.* (1992) split application of nitrogen fertilizer produced significantly higher head rice recovery.

According to Bandyopadhyay and Roy (1992) head rice yield of a variety depends upon moisture content of the grain during harvest. The paddy harvested at higher moisture content (21-24 per cent wet basis) and dried by a mechanical drier gives better yield of milled rice when compared to paddy dried in the sun. He also stated that pre-treatment methods such as soaking during parboiling helps in increasing the head yield.

Ali *et al.* (1993) had reported that head rice recovery was low at early and late maturity stages.

Karim *et al.* (1993) found that the percentages of milled rice and head rice yield of Basmati-385 decreased gradually as milling pressure increased.

Ali *et al.* (1993) had suggested that harvesting rice at optimum maturity is important for obtaining high milling recovery and good cooking quality.

2.2 COOKING CHARACTERISTICS

Cooking quality is usually defined by (i) the time required for proper cooking (ii) the increase of volume of the cooked product (iii) consistency and (iv) loss of solids during cooking (Bandyopadhyay and Roy, 1992). Cooking characteristics play a vital role in determining the quality of rice.

According to Mahadevappa and Desikachar (1968) the swelling number, water uptake, formation of cracks in rice on wetting, expansion in length, breadth and lateral thickness are important ones. Juliano (1979) had observed that some of the properties of rice were closely related to other qualities of rice such as volume expansion, water absorption and resistance to disintegration of milled rice during cooking. Juliano (1985) had stated that the quality of rice can be further improved in terms of cooking properties, nutrient content, colour and flavour by adopting improved practices for processing of paddy. The desirable quality attributes include clear whole grain for raw milled rice and desirable cooked rice texture, depending on the texture preference in each area. The author had also reported that there was a definite relationship between the physico chemical characters and cooking quality of rice varieties.

Swaminathan (1988) had stated that the cooking quality of rice can be expressed in terms of consistency (pasty or separate grains) and swelling number. He had also reported that the storage of freshly harvested paddy for 6-12 months brings about a marked improvement in the cooking quality of rice.

A study conducted by Geervani and George (1971) had revealed that traditional varieties were found to be much inferior in cooking quality when compared to high yielding varieties of rice evolved at Andhra Pradesh.

Bhat and Rani (1982) evaluated the cooking and nutritive value of high yielding rice varieties and reported that among the varieties studied, cooked *PR*-106 got the highest mean scores for colour, taste, flavour, texture, doneness and overall acceptability. According to the author *PR-106* also had the largest volume after cooking, water absorption during cooking, elongation and swelling ratios.

2.2.1 Optimum cooking time

Juliano (1967) had revealed that cooking time and gelatinization temperature of milled rice correlated positively. According to Govindaswamy and Ghosh (1970) the cooking time was positively correlated with the protein content. Raghavendra Rao and Juliano (1970) had opined that parboiled low amylose samples cooked 1.5 minutes faster than raw kernels.

Priestley (1976b) had stated that parboiled rice generally takes longer time to cook than raw rice. The author also stated that irradiated rice samples showed differences in cooking time. A tendency toward decreased cooking time was observed as dose level increased.

Sabularse *et al.* (1981) revealed that cooking time was not significantly affected by storage. According to Chatterjee and Maiti (1981) rice with high (more than 10 per cent) protein content or a high gelatinization temperature (of 74^{0}C or higher) require more water and a longer cooking time to produce a cooked rice with the same degree of doneness as rice with lower values for these properties.

Vandrasekh and Warthesen (1987) had reported that thermal degradation was slower in brown than in white rice but the extended cooking period regained for attaining tenderness in brown rice was observed to result in a greater percentage of thiamine loss.

2.2.2 Water uptake

It is a measure of the hydration characteristics of rice, which may be influenced by such factors as the gelatinization temperature and porosity of the kernel (Bandyopadhyay and Roy, 1992). Increasing temperatures at soaking of paddy during parboiling upto 60°C had no or only slight effect on the water uptake of the resulting rice during cooking. But the water uptake of parboiled rice was progressively reduced when the paddy had been soaked at 70°C and above (Bhattacharya and Subba Rao, 1966).

Govindaswamy and Ghosh (1970) had stated that the water absorption ratio was negatively correlated with the protein content. Bhattacharya and Sowbhagya (1971) had found that the uptake of water is found to be related to the surface area. The uptake of water per gram of rice grain with a definite time of cooking is always high for small and slender varieties, because they have relatively high surface area per gram. The author had also reported that the uptake of water is strongly influenced by the gelatinization temperature. The lower the gelatinization temperature of the variety, the higher will be its water uptake at 70°C - 80°C and vice versa.

Geervani and George (1971) had found that size of the grain and cooking temperature influenced the hydration characteristics of the rice grains. Sekhon *et al.* (1980) had opined that among the varieties studied *Basmati* 370 had best cooking qualities. Pillaiyar and Mohandoss (1981c) had reported that the cooking characteristics of parboiled rice were influenced by the hydration behaviour of rice at temperature above and below the gelatinization point.

Juliano and Perez (1984) had found that water rice ratio for acceptable soft texture increased with increasing amylose.

According to Damir (1985) the parboiled grains were shorter but wider with lower water absorption and swelling capacity during cooking than those of raw milled rice.

Govindaswamy (1985) had found that a high water uptake in boiling water was an indicator of good cooking quality of rice. According to Karim *et al.* (1993) the water absorption ratio is maximum at the intermediate milling pressures of 2.0 and 2.5.

2.2.3 Gruel loss

Bhattacharya and Subba Rao (1966) had reported that higher the gruel loss, greater will be the nutrient loss. The loss of solids in the gruel of raw, soft parboiled and hard parboiled rice was 4.5, 3.5 and 2 per cent respectively. The author also stated that the loss of solids in the gruel of parboiled rice was minimum when compared to raw rice. According to Rajalakshmi (1984) decreased gruel loss during cooking is advantageous nutritionally.

2.2.4 Volume expansion

Govindaswamy *et al.* (1969) had stated that kernel expansion or volume expansion is determined from the ratio of the cooked volume of rice to that of the uncooked rice. It ranged 2.0 to 4.35 times in most of the varieties. Kurien *et al.* (1964) had found that parboiled rice grains after cooking appeared bigger and bolder than cooked raw rice. According to Mahadevappa and Desikachar (1968) the percentage expansion was found to be significantly decreased for parboiled rice when compared to raw rice samples.

Higher volume expansion after cooking is a desirable trait preferred by consumers. Increase in water uptake also directly influences the volume expansion of rice varieties (Sreedevi, 1989). A study conducted by Gupta (1990) among 15 rice varieties of West Bengal revealed that the volume expansion ranged between 3.81 to 5.45.

2.2.5 Gelatinization temperature

According to Govindaswamy (1985) the gelatinization temperature of starch is the range of temperature with in which it starts to swell irreversibly in hot water with a simultaneous loss of crystallinity. This temperature varies in varieties from 56 to 79^{0}C.

The gelatinization temperature of rice starch is positively related to the time required to cook milled rice (Beachell and Halick, 1957; Juliano *et al.*, 1965).

Nirmala and Philomina (1971) had indicated that the rice varieties with large and long grains tend to give acceptable products on cooking and tend to form good gels. They had also reported that varieties with small size kernels tend to give sticky products on cooking which are not generally acceptable. Swaminathan *et al.* (1971) had stated that the gelatinization temperature is positively correlated with the cooking time.

Bhattacharya and Sowbhagya (1972) had reported that the degradation pattern of the parboiled kernels immersed in alkali became swollen and gelatinized without significant corrosion or kernel opening. The degraded kernels were more compact with much narrower collar than in the raw rice.

In a report published by IRRI (1977) most waxy rices have low starch gelatinization temperature. Studies indicated that gelatinization temperature is related to texture of cooked rice among waxy rices.

Ali and Bhattacharya (1980) had reported that parboiled rice viscograms show a higher gelatinization temperature when compared to raw rice and when studied under identical slurry concentrations. Chatterji and Maiti (1981) had stated that rice with high (more than 10 per cent) protein content or a high gelatinization temperature (74^{o}C or higher) require more water and a longer cooking time to produce a cooked rice with the same degree of doneness as rice with lower values for these properties.

Ali and Bhattacharya (1980) had reported that parboiled rice viscogram show a higher gelatinization temperature when compared to raw rice. Nakazava *et al.* (1984) had opined that gelatinization on set temperature was significantly affected by starch fraction level in the rice suspension. Zaman *et al.* (1985) had pointed out that the gelatinization temperature of brown rice and milled rice increased significantly with time. Yu *et al.* (1990) had stated that gelatinization temperature of milled rice is low.

According to Bandyopadhyay and Roy (1992) the gelatinization temperature influences the cooking behaviour. The greater the degree of gelatinization, the higher is the hydration ability of the resultant rice of temperatures below 70^{o}C. The authors also found that the gelatinization temperature influenced the cooking behaviour. The greater the degree of gelatinization, the higher is the hydration ability of the resultant rice of temperatures below 75°C. Above the gelatinization point, the rate of hydration decreases on parboiling, the extent of decrease being again proportional to the severity of parboiling.

2.2.6 Elongation ratio

According to Mahadevappa and Desikachar (1968) expansion in length, breadth and lateral thickness of rice are important parameters. Pillaiyar and Mohandoss (1981c) had stated that kernel elongation on cooking is an important factor which influences the cooking qualities of rice. They also reported that the temperature of parboiling influenced the linear elongation of the kernel after cooking. A slight decrease in the elongation ratio after parboiling was also noticed by the same author.

Chinnaswamy and Bhattacharya (1983) reported that raw and mildy parboiled rice gave minimal expansion which increased with increasing severity of parboiling upto a steam pressure of 1.5 Kg /cm^2. They had also reported that rice parboiled by heating with sand (250°C, 2.5 minute) expanded best and addition of salt increased this expansion.

In a report of IRRI (1986) it has been stated that some varieties increase hundred per cent in length during cooking a desired trait in high quality rices. Pillaiyar (1988) had stated that increase in milling to 8 per cent nominally increased the elongation ratio. In a study conducted by Gupta (1990) in West Bengal among 15 rice varieties revealed that the elongation ratio ranged between 1.74 to 1.22. Ali *et al.* (1993) reported that rice stored as milled grain improved in cooking quality as it aged and recorded greater elongation.

2.2.7 Elongation index

Elongation index is related to grain dimension. The elongation index will give an idea of the percentage increase in grain dimension after cooking which is a desirable trait while estimating the acceptability of the varieties. Damir (1985) had stated that the parboiled grains were shorter but wider with lower absorption and swelling capacity during cooking than those of raw milled rice.

2.2.8 Viscosity

In a report from IRRI (1963) it has been indicated that increase in protein content of a variety results in the suppression of amylogram viscosity. Tani *et al.* (1969) had reported that high multiple correlation coefficients observed among palatability evaluation, water uptake ratio, expanded volume on cooking, elasticity and apparent viscosity. High amylose (25 per cent) rice show a drastic drop in peak viscosity upon parboiling as compared with low amylose rice (Raghavendra Rao and Juliano, 1970).

2.2.9 Heat alteration value

It is a procedure for predicting cohesiveness characteristics of rice varieties when cooked. This test constitutes another method of measuring the probable gelatinization potential of rice starch. Samples of high gelatinization temperature show few granules slightly altered (low-heat alteration value). Low gelatinization temperature show most granules greatly altered (high-heat alteration values). Parboiling induces a certain amount of heat alteration in rice, varying from slight to great, depending on the type of rice and on the parboiling conditions (Anon., 1965).

2.2.10 Sedimentation value

The test is a measure of the insoluble solids lost to the treating solution at the specified temperature. According to Bandyopadhyay and Roy (1992) it is influenced by the gelatinization temperature and the physical structure of the kernel. They also reported that the sedimentation value of parboiled rice is about one-fourth that of raw samples. The author also reported that the sedimentation value of parboiled rice is about one fourth that of raw samples.

2.2.11 Starch-Iodine blue value

According to Bandyopadhyay and Roy (1992) the reaction between amylose and iodine serves as the basis of the very useful starch- iodine blue test which is indicative of the amylose soluble under the conditions of measurement. Since it shows a close correlation with total amylose content, the value is another measure of cooking behaviour.

2.2.12 Alkali spreading

According to Bandyopadhyay and Roy (1992) this is a well known test of rice kernels immersed in a dilute solution of alkali, when the extent of degradation undergone by a variety gives an inverse estimate of its gelatinization temperature. The reaction shows distinctive difference between the raw and parboiled rice kernels.

2.3 ORGANOLEPTIC QUALITIES

Araullo *et al.* (1976) had observed that the palatability characteristics (Colour, appearance, cohesiveness, tenderness and flavour) contribute an important factor in grading the quality of rice. From the months of survey conducted among 41 respondents Juliano (1982) stated that most of them were interested to cooperate testing of methods including sensory evaluation and instrument evaluation to determine the quality of rice grains.

International Organization for Standardization (1985) had indicated that the cooking behaviour of rice was evaluated by determining certain visco elastic properties after cooking like swelling, firmness, elastic recovery and visco elastic index using a visco elastography. Lii and Chang (1986) had stated that the eating quality of rice is usually judged by the sensory evaluation which seems unscientific and variable according to personal preference.

According to Abansi and Duff (1988) a study of consumer preferences for rice quality was conducted to evaluate the relationship between price and quality using a hedonic pricing model and consumer categories by location (urban Vs rural) in three income classes viz., low, medium and high. Physical and chemical characteristics considered were whiteness, translucency, shape, foreign matter content, head rice percentage, amylose content and alkali spread. Buying decisions were dependent on physical and chemical characteristics. Consumers select these qualities indirectly through induction using appearance and sensory assessment.

Sreedevi (1989) had observed through sensory evaluation studies that the acceptability of the cooked rice samples was influenced by the physical characteristics. Bruce *et al.* (1991) had stated that the important factors in the marketing of rice are its cooking, eating and processing qualities. This includes the texture, integrity, flavour and appearance of the cooked grain.

Bandyopadhyay and Roy (1992) had stated that the attributes of appearance, tenderness and flavour of cooked rice are the final criteria of cooking quality and determine the palatability or eating characteristics of cooked rice.

Roberts (1978) had reported that data from an acceptability trial indicated that about half of the panel preferred the lightly milled samples while the other half the conventional well-milled white rice.

According to Ikehaski and Khush (1979) chalkiness and whiteness of milled rice were two of the most conspicuous factors determining its commercial value. They had further stated that visual rating of these traits had been the most common method.

2.3.1 Colour

Parboiling affects colour of the product. A major disadvantage of parboiled rice is the yellow colour of the kernel. Processing conditions prevailing during steeping and steaming are responsible for the relative colouring of parboiled milled rice.

Roberts *et al.* (1954) had indicated that the temperature and time of soaking had lesser effect on colour development, but the steaming temperature had more effect. Studies conducted by Central Food Technological Research Institute (1960) had reported that the colour of parboiled rice produced under different conditions varied from yellowish to yellowish brown or light tan to deep amber.

Jayanarayanan (1965) and Refai *et al.* (1967) had stated that amylose activity during soaking influenced considerably the colour formation in parboiled rice and the discolouration increased on either side of pH 4.5 during soaking. He had also reported that soaking paddy at 70^{o}C in water containing 0.1 to 0.6 per cent sodium bisulphite inhibited discolouration in parboiled rice. Bhattacharya and Sowbhagya (1971) had found that the colour of rice when parboiled, was found to be influenced by enzymatic browning, the husk pigment and the bran.

Soaking methods also significantly influenced the colour in parboiled rice. Among cold, warm and hot soaking methods, cold soaking had the least colour inducing effect on rice and the hot soaking the most (Pillaiyar and Mohandoss, 1981b). Pillaiyar (1981) had found that it is preferable to steep paddy at a temperature below 60°C and complete the parboiling at or below 90°C to eliminate the colour formation in parboiling.

Patil *et al.* (1982) had found that the colour was more deep in the pressure parboiled samples (yellowness index 1.91) and less in the double steamed samples (yellowness index: 1.32). Sekhon and Anand (1983) had reported that pressure steaming treatments adopted in rice processing was reported to improve the appearance and decrease the stickiness but imparted slight discolouration and increased hardness of the cooked rice samples.

Sharp *et al.* (1985) reported that increased roasting time in parboiled milled rice resulted in decreased whiteness and yellowness and increased redness but the intensity of the colour change was diminished by hydration. According to Sreedevi (1989) compared to raw rice samples the parboiled samples were observed to be less acceptable, on the basis of the quality attribute colour. But Mohandoss and Pillaiyar (1978) did not find any influence of soak water pH on colour within a range of 4.5 to 7.0

The drying temperature also influenced the rice colour. The whiteness of parboiled rice was reduced while increasing the drying temperature of parboiled paddy. Vasan and Usharani (1980) had also observed a deep colour in the pressure parboiled rice and light colour in the single steamed sample. According to Mohandoss and Pillaiyar (1978) the retention of parboiled paddy in hot condition aggravated the colour.

2.3.2 Texture

According to Juliano (1970) amylose content mainly determine the texture of cooked rice. But in samples of similar amylose content, including those of the same variety, protein content is the major influence in texture. Cagampang *et al.* (1973) stated that unlike in low amylose rices which are inherently associated with soft texture in high amylose rice, the texture varies as demonstrated by the parameters of gel consistency. According to priestley (1976 b) hardness in the texture of *IR*-8 samples may be due to the extreme apparent starch solubilization during parboiling or to the extent of amylose retrogradation after parboiling.

Bhattacharya *et al.* (1978) had reported that the stickiness and consistency of cooked rice and viscogram characteristics could not be explained on the basis of the total amylose content alone but they correlated well with the insoluble amylose content. They had also stated that as the insoluble amylose increased and the stickiness and breakdown decreased. According Mohandoss and Pillaiyar (1980) the raw cooked sample was scored to be soft and the parboiled rice hard.

Pillaiyar and Mohandoss (1981a) developed a pressing device to measure the texture of cooked rice. The results of the experiments suggested that the pressed area of the cooked rice and length breadth ratio of uncooked samples correlated positively. The pressed area was correlated negatively with the temperature of parboiling.

Mohandoss and Pillaiyar (1982) had reported that within the same parboiling conditions the palatability varies among different varieties. The texture in the cooked and *IR* 20 samples of single steamed, double steamed and hot soaked processed was moderately tender, to tender and well separated, whereas ~~that of~~ pressure parboiled samples was tough and well separated. The texture of pressure parboiled samples of *IR*-8 was very tough.

Juliano and Perez (1984) also reported that water rice ratio for acceptable soft texture increased with increasing amylose content of the samples.

Pillaiyar (1984) had found out a rapid test to measure the texture of parboiled rice without cooking. The results of the study indicated that the gel strength was significantly more for parboiled rice varieties than for raw rice varieties. The author had also reported that the gel strength of the parboiled rice varieties were reported to increase significantly expressing the negative correlation with the texture of cooked grains.

The tenderness (soft or hard) in cooked rice is the deciding factor in evaluating the palatability of parboiled rice. The cohesiveness of the cooked kernels of different parboiled samples generally play a major role in modifying the palatability of cooked parboiled rice.

Unnikrishnan and Bhattacharya (1987) studied the influence of varietal differences on properties of parboiled rice and reported that hydration, amylose solubility, gel mobility, pasting behaviour, slurry viscosity and texture of cooked rice samples were the characteristic generally influenced due to parboiling. The author had also indicated that the initial gradation of properties among the different varieties were reported to remain largely unchanged after parboiling and although rice became harder and less sticky after parboiling. However, his observations further revealed that a sticky variety remained relatively sticky and a non-sticky variety relatively non-sticky. Swaminathan (1988) had stated that the storage of freshly harvested paddy for 6-12 months brings about a marked improvement in the cooking quality of rice.

2.3.3 Adhesiveness

According to Sreedevi (1989) popular local rice varieties in Kerala obtained a higher mean score for adhesiveness when compared to high yielding varieties evolved. She had also stated that the quality parameter adhesiveness was found to be negatively influenced by parboiling.

2.3.4 Flavour

Jennings *et al.* (1979) had developed a simple laboratory test to evaluate aroma of different rice varieties at International Rice Research Institute. The aroma was rated as strong, intermediate, slight or absent in comparison with a strongly scented variety. In both the single and double steaming processes, the soak water emitted off-odour in 24 hr. and then the odour intensified.

According to Purela (1975) the development of off-odour was ascribed to the growth and activity of coliform bacteria and to the multiplication of both yeasts and bacteria.

Ali and Bhattacharya (1980) and Anthoni Raj and Singaravadivel (1980) reported that the sugars and aminoacids that leach out of paddy during soaking serve as a good medium for the prolific activity of microorganisms and fermentation changes.

According to Pillaiyar (1980) development of off-odour could be prevented by treating the soak water with chromium trioxide at 0.03 per cent level, sodium and potassium chromates at 0.05 per cent, copper sulphate, mercuric chloride, silver nitrate and ammonium molybdate at 0.30 per cent.

Parboiled rice has a characteristic taste and aroma which is accepted only by the traditional rice-eating people. According to Bandyopadhyay and Roy (1992) the flavour of the parboiled product is the result of hydrolysis and decomposition of certain constituents such as carbohydrates, proteins, under the influence of steam at high temperature during parboiling. They also reported that the secondary products responsible for the characteristic flavour are the protein consisting of the sulphur containing amino acids which produce sulphurous compound (mercaptans) having a characteristic flavour and aroma.

Cerida *et al.* (1983) graded the cooked rice for taste, smell, colour and overall impression. Tabulated results showed no significant difference between unsoaked control and rice soaked at 60°C was rejected because of its unpleasant flavour.

During fermentation the pH was reported to fall from 6.0 to 4.3- 5.3 and acidity increased from 3.2 to 19.0 ml. of 0.IN lactic acid per 25 g. iddli batter (Steinkrans *et al.* (1967) He had also observed that the batter should raise approximately 50 per cent above its original volume but the batter may rise by as much as three times it original volume.

According to Van Veen *et al.* (1968) fermentation of unhusked rice resulted in an increase in protein and fat eventhough the final product has brownish yellow colour. Reddy and Salunkha (1980) had found that the mixture with 1 per cent salt fermented for 20 hours gives soft products (iddli) and had phytate phosphorus upto 1.5mg/g. of phytate phosphorus. They had also reported that fermentation of iddli mixture had no effect on the content of calcium, magnesium, zinc and iron.

Vasan and Kausalya (1981) standardised beverages like tea and coffee and sweet preparation of acceptable quality with staple milk prepared from rice germ. They also found that the rice germ could be added upto 20 per cent of rice flour in dosa preparation.

Studies conducted by Sarasa and Nath (1985) on the gas retaining capacity of rice batter by measuring its volume for 24 hours at 4 hours intervals. They reported that although both batter volume and displaced volume of the test batters increased tremendously at 12 hours of fermentation, they attained a maximum at 16 hours of fermentation, and got stabilized thereafter.

Venkatasubhaiah (1985) had found that addition of glucose (1 per cent) in iddli batter did not significantly improve fermentation efficiency. Lee *et al.* (1986) had reported that the average relative nutritive value of protein increased by 11 per cent during fermentation whereas thiamine decreased by 50 per cent and the riboflavin content doubled.

2.4 NUTRITIONAL COMPOSITION

The nutritional composition of rice grains is a major parameter influencing the quality of rice grains. Under this the calorific value, protein content, calcium, iron, phosphorus, starch, ash content, crude fibre, amylose content and vitamins are mainly considered.

2.4.1 Calorific value

According to Juliano (1985) although rice is primarily a source of carbohydrate, it also deserves to have the highest digestibility, biological value and protein efficiency ratio among all the cereals. The calorific value is meant to determine the carbohydrate content of rice which is composed of amylose and amylopectin. 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. She further observed that calorific value increased after parboiling which is attributed due to the imbibition of rice bran oil into the endosperm at the time of parboiling which enables a higher calorific value to be shown by the rice grains obtained after parboiling.

2.4.2 Protein

Rice is considered to be a major source of dietary protein in Indian diets where the protein content is low but the quality is superior. Okazaki and Oki (1961) found that rice varieties that cook well contained considerable amount of protein constituents, such as aminoacids like glutamic acid, aspartic acid and arginine.

The protein content and the thickness of the aleurone layer were greater in coarse varieties (Anon., 1963). Guha and Mitra (1963) observed that in the brown rice of 74 varieties collected from U.P, West Bengal, Orissa and Madras, the protein content ranged from 6.7 to 11.0g per cent.

Environment may influence the protein content of a variety. Juliano *et al.* (1964) stated that protein values over 10g per cent may be due to environmental factors. Protein content in milled rice varied from 5 to 14 per cent (Juliano, 1966). Mathur (1967) reported that the *NP*-130, *Taichung* (Native) and *IR*-8 varied from 10.1 to 11.5g per cent.

Patel and Rajani (1967) found a variation of 6.5 to 12.5g per cent in the protein content in some of the varieties from Gujarat. From histological studies Mahadevappa and Desikachar (1968) found that protein was distributed predominantly in the aleurone and sub aleurone cells in both raw and parboiled kernels. Webb *et al.* (1968) observed that protein content is influenced by parboiling.

Govindaswamy *et al.* (1969) reported a protein range from 6 to 12 per cent (wet basis) on 300 improved commercial varieties. He had also reported that there was no association between the size of the grain and the protein content. Misra and Sampath (1969) found a variation of 7 to 5g per cent in the *Taichung 65* and in six crosses of rice and it varied from 6.69 to 8.85g per cent. Prema and Menon (1969) had shown that protein content was higher in exotic rice varieties like *Tainan* 3 and *IR* 8 when compared to local varieties like *Kochuvithu*. Of the ten varieties tested by Srinivasa Rao and Ramasastri (1969) six had protein content over 9g per cent. According to the author Indian rice varieties contained protein in the range of 11 to 13g per cent. But Chandrasekhar and Mulk (1970) conducted studies on the nutritive value of 3 high yielding varieties of rice viz., *Jaya*, *Padma* and *Hamsa* and reported that Hamsa recorded highest protein content and variety Jaya had the best isoleucine: leucine ratio. Singh and Singh (1970) analysed the protein content in dehulled grains of 12 varieties and found it highest in *T 43*, *N 22* and *T 21*.

Baba (1971) studied the variability in protein content in 40 rice varieties under cultivation in Kashmir. The varieties showed a variation from 6.56 to 12.86g per cent. He has classified the varieties into 3 groups viz., group I having a protein range 11.07 to 12.86g per cent, group II with a range of 7.87 to 10.93g per cent and group III with a range of 6.56 to 7.77g per cent.

Devadas *et al.* (1968); Dimopoulos and Muller (1972); and Damir (1985) observed a slight increase in protein content in the milled parboiled rice. But according to Subramanian and Dakshinamoorthy (1977) and Anothoni Raj and Singaravadivel (1980) the protein content dropped slightly during parboiling because of leaching out of non-protein nitrogen and also decreased in total free amino acids.

Geervani and George (1971) from Andhra Pradesh reported that varieties such as *Pankaj, Hamsa* and *HR-35* had high protein content and dense distribution of protein in the endosperm. They also reported that *Jaya* had a low percentage of albumin fractions. Tara and Bains (1971) had reported that milled rice when cooked experienced a negligible loss of lysine and threonine. A slight decrease of lysine in parboiled rice was due to the longer cooking time. Barber (1972) had stated that additional nitrogen application particularly at heading stage, always increased the protein content. Govindaswamy and Ghosh (1973) reported that protein content ranging from 5.5 to 13g per cent in Indian varieties of rice. Mahadevappa and Shankara Gowde (1973) had found 6 to 11g per cent protein in sixty rice varieties studied. According to Wahid *et al.* (1975) there was a significant difference in the protein content between unpolished and polished rice of different varieties.

Dutta and Barua (1978a) found lower protein content and better distribution of essential amino acids in some of the high yielding varieties of Assam than in most of protein rich varieties. Reports from IRRI (1978) showed that protein content in brown rice varied from 4.3 to 18.2g per cent. Studies by Shekhon *et al.* (1980) on 6 high yielding varieties of Punjab showed that the lysine content ranged from 3.25 to 3.50g per cent. According to Bhat and Rani (1982) the protein content of high yielding varieties on dry matter basis ranged from 6.68 to 7.43g per cent. They also reported that in coarse rice protein content and the thickness of aleurone layer were reported to be greater.

Ellis *et al.* (1986) reported that the endosperm storage protein decreased in amount with increasing distance from the aleurone layer. Ullah and Khondaker (1988) had found a positive correlation between grain protein content and yield. Sreedevi (1989) after studying 9 high yielding varieties of Kerala Agricultural University and 4 local varieties reported higher protein content in the former varieties. Sikka *et al.* (1993) found that with increasing doses of nitrogen fertilizer, there was an increase in the protein content.

2.4.3 Starch

According to schoch (1967) and Kaul (1970) rice starch like other starches, contain both amylose (linear fraction) and amylopectin (branched fraction). The amylose content of non-waxy milled rice may constitute 7 to 33 per cent of its dry weight, whereas waxy rice has an apparent amylose content of 0.8 to 1.3 per cent. He also added that amylopectin is the major starch constituent and is the only starch fraction of waxy rice.

Aberg (1994) had found that starch is the major constituent in cereal grain and is the nutritional reservoir in plants and exists in 2 different forms. Amylose, the unbranched type of starch, consists of glucose residues in 1-4 linkage, amylopectin, the branched form, has about one 1-6 linkage per every thirty 1-4 linkage. According to Singh (1993) starch is a mixture of amylose and amylopectin. The ratio of amylose to amylopectin in starch is characteristic of the plant species and is under genetic control.

Resurreccion *et al.*(1979) reported that the constituents decreased from the surface to the centre of the grain in both raw and parboiled rice. They also found that starch, and amylose content in starch increased progressively from the surface to the centre of the grain. Bhat and Rani (1982) had opined that among the varieties analysed raw rice variety *PR* 106 had the highest amount of starch and *Jhana* 349 had the lowest amount. According to Aberg (1994) protein is negatively correlated to the starch content.

But Kuzimina and Torzhins kaya (1973) had found a loss in the starch content as a result of parboiling. Ali and Bhattacharya (1976) had stated that the total starch content was unaltered in parboiling but the soluble amylose content was increased depending upon the severity of parboiling. They also reported that the amylose; amylopectin ratio did not vary considerably during parboiling. According to Esmay *et al.* (1979) parboiling gelatinizes the starch within the rice grain, thus causing swelling and fusion of starch with in the kernel. Anthoni Raj and Singaravadivel (1980) had found that considerable changes in sugars and aminoacids occurred during soaking.

2.4.4 Amylose content

Kaul (1970) had reported that rice starch is composed of a linear molecular component amylose and a branched chain component amylopectin. He had further reported that the proportion between these two types determine the texture of cooked rice. The author also stated that rice with high amylose cook dry and fluffy while high amylopectin containing rice result in a moist and sticky mass. According to Raghavendra Rao and Juliano (1970) the amylose content varies from 15 to 37 per cent in rice.

Juliano (1972) and Perez and Juliano (1988) had reported that rice are classified as waxy (containing 0.2 per cent amylose) and non waxy very low (2-8 per cent); low (9-20 per cent); intermediate (20-24 per cent); and high (25-33 per cent) based on amylose content.

In a study conducted by Alary *et al.* (1977) using 49 varieties of rice, the amylose content varied from 21.6 to 29.2 per cent. Paule (1977) had stated that the same variety grown under different environments can fall into different amylose groups. Resurreccion *et al.* (1977) reported that ambient temperatures during grain development affects the rate of starch deposition and its properties, a higher temperature can cause a lower amylose content.

Sidhu *et al.* (1975) had reported that there was a considerable increase (5.3 to 8.4 per cent) in the amylose content of rice of each variety with the increase in polishing. According to Unnevehr *et al.* (1985) consumers generally prefer rice with intermediate amylose. Stickiness of cooked rice and amylose content of raw rice was studied using IRRI varieties and the stickiness of cooked rice was more closely related to amylose content (Anon., 1986). Juliano *et al.* (1987) had reported that among three high amylose starches, differing in gel consistency, the hard gel starch corresponding to hard cooked rice had higher amylograph consistency and set back high gel viscosity in 0.2 N potassium hydroxide and higher alkali viscograph peak than starch with soft or medium gel consistency. Hard gel consistency starch had less extractable starch and amylose in boiling water than soft or medium gel consistency starches. The three starches had similar amylose, the difference in gel consistency were due to the amylopectin fraction. Bai *et al.* (1991) had found that the amylose content of Moncompu varieties vary from 16 per cent to 21.9 per cent.

2.4.5 Crude fibre

Rice is reported to be a moderate source of fibre. Dutta and Barua (1978b) found that rice with only the husk removed had more crude fibre than well milled rice and showed a lower digestibility and retention of nitrogen. Eggum (1979) had stated that the low content of tannin and crude fibre in rice had positively influenced the digestibility of rice protein and energy. According to Pillaiyar (1979) brown rice constituted 0.7 per cent crude fibre and 0.1 per cent dietary fibre whereas milled rice had 0.1 per cent crude fibre and 0.6 per cent dietary fibre.

2.4.6 Minerals

Doesthale *et al.* (1979) had found that the degree of milling and the initial content of mineral in grain determined the magnitude of loss on milling. They had also reported that parboiling altered the distribution of minerals except zinc, magnesium and cobalt. Damir (1985) stated that the minerals, in rice grain increased as a result of parboiling.

Pederson and Eggum (1983) had reported that the mineral content in different rice varieties decreased considerably during milling and the extent of decrease differed between minerals.

Rajalakshmi (1984) had stated that the iron content was found to increase as a result of parboiling. The increase in iron content due to parboiling was also reported by Damir (1985).

2.4.7 Ash content

The ash content of a foodstuff is the inorganic residue remaining after the organic matter has been burnt away (Kirk and Sawyer, 1991).

2.4.8 Calcium

Rice is reported to be a moderate source of minerals. According to Dutta and Barua (1978b) calcium content of rice varieties varied from 15.77 to 29.70mg/100g. He had also reported higher values of calcium in some of the high yielding varieties. Bhat and Rani (1982) reported that the calcium content of raw rice varied from 8.0 to 16.0mg per cent.

Sood *et al.* (1980) had reported that rice bran contained maximum calcium, potassium, magnesium and phosphorus while milled rice contained the lowest level in all the tested rice varieties. While, Sreedevi (1989) recorded lesser calcium content in local varieties compared to high yielding varieties evolved by Kerala Agricultural University.

According to Ocker *et al.* (1976) the severity of steaming in parboiling greatly influenced the mineral distribution in parboiled rice. Steaming increased the calcium content of the treated milled rice samples compared with that of the raw milled rice. The increase became more noticeable after soaking the paddy samples for 18 hours, but soaking for 24 hours resulted in a loss of calcium content of rice.

2.4.9 Iron

According to Dutta and Barua (1978a) the iron content of the different rice varieties grown in Assam was lower in comparison with the varieties from other parts of the country. Chandrasekharan and Mulk (1970) reported highest iron content in rice variety *Jaya*. But Damir (1985) had found that puffed rice contain high amount of iron.

The milling losses varied in magnitude for different elements and were directly proportional to the degree of milling. According to Barber (1972) in commercially milled rice, removal of the outer layers, which constitute approximately 5 per cent of the whole kernel by weight, was shown to result in 40 per cent reduction in total ash and phosphorus, 66 per cent calcium and a very high percentage of loss in iron content of the grain. The zinc content of the rice grain was found to be remarkably constant, as it was not affected by the process of milling.

2.4.10 Phosphorus

Hussain *et al.* (1987) had opined that red grain varieties had higher phosphorus content than white varieties. But according to Miyoshi *et al.* (1987) phosphorus balance was negative in brown rice.

Sreedevi (1989) also had reported a decrease in phosphorus content during parboiling. But Pillaiyar (1988) had found that phosphorus content of parboiled rice samples was higher compared with that of raw milled rice.

2.4.11. Fat

Rice contain negligible amount of fat which is unevenly distributed with in the endosperm, the highest concentration being in the outer layer and the lowest in the central portion. (Normand *et al.,* 1966; Houston, 1967; Hogan *et al.*, 1968). According to Dutta and Barua (1978b) the scented and sticky rice varieties were reported to contain higher amounts of lipids. The lipid content of brown rice ranged from 2 to 4 per cent with higher concentration in the outer layers.

According to Desikachar *et al.* (1969); Shaheen *et al.* (1975); Kumaresan and Sree Ramulu (1978) parboiling decrease the free fatty acid content in the bran oil. The decrease in free fatty acid as a result of parboiling, was due to its complexing with amylose, more severe the parboiling, more was the complexing and so was the reduction in the free fatty acid content.

According to Bandyopadhyay and Roy (1992) the oil content of bran obtained from parboiled paddy becomes more than that obtained from raw rice.

2.4.12 Vitamins

Rice is the major source of Vitamin B Complex in the diet of Asians. According to Juliano (1970) among the water soluble B - Vitamins, thiamine is present in a larger proportion in the bran layers and embryo than riboflavin and niacin. Narunnabi *et al.* (1975) had found that thiamine, riboflavin and niacin contents of husked rice varied significantly and were influenced by different parboiling methods.

Dutta and Barua (1978b) had found that high yielding varieties were reported to be relatively poor sources of vitamins except riboflavin.

In a report of NIN (1978) it has been stated that the thiamine content of brown rice ranged between 0.35 and 0.44 mg/100g.

Vandrasek and Warthesan (1987) had reported a initial thiamine leaching by thiamine uptake as water was absorbed during cooking of white rice. He also reported that the extended cooking time required for tenderness in brown rice resulted in a greater percentage of the thiamine loss.

MATERIALS AND METHODS

MATERIALS AND METHODS

The study entitled "A multi variate approach to define the quality of rice" (Oryza Sativa) envisages a critical assessment of various parameters like physical characteristics, cooking characteristics, organoleptic qualities and nutritional composition for developing a comprehensive index to define the quality of rice through a multivariate approach.

3.1. RICE VARIETIES SELECTED

Three categories of rice viz., hybrid derivatives, traditional varieties and other improved/market varieties were selected for the study. The three categories were selected because of the variation in their qualities . This further enables to find out to the extent to which the quality of a hybrid derivative differs from its parents.

Sixty rice varieties were collected for the study. Among these, thirty varieties were hybrid derivatives, twenty eight were traditional/local varieties and the remaining two were other improved/market varieties. These varieties were included in the study based on their general acceptability in the State for various purposes. The varieties are presented in Table 1.0

Table 1.0 Rice varieties selected

Sl. No.	Hybrid derivatives	Sl. No.	Traditional/ local varieties	Sl. No.	Other improved/ market varieties
1	*Annapoorna* (Ptb 35)	31	*Aruvakkari* (Ptb 32)	59	*CO - 25*
2	*Aruna* (MO8)	32	*Aryankali*	60	*Mashuri*
3	*Asha* (MO5)	33	*Aryan* (Ptb 1)		
4	*Bhadra* (MO4)	34	*Chenkayama* (Ptb 26)		
5	*Bharathy* (Ptb 41)	35	*Cheriya Aryan* (Ptb 23)		
6	*Bhagya* (Kylm 2)	36	*Chettivirippu*		
7	*CSRC collection*	37	*Chitteni* (Ptb 12)		
8	*Dhanya* (Kylm - 4)	38	*Chuvannamodan* (Ptb 30)		
9	*Hraswa*	39	*Chuvannari Thavalakannan* (Ptb 8)		
10	*Jaya*	40	*Elappapoochemban* (Ptb 31)		
11	*Jayathi* (Ptb 46)	41	*Kattamodan* (Ptb 28)		
12	*Jyothi* (Ptb 39)	42	*Kutticheradi*		
13	*Kanakom* (MO 11)	43	*Kuruwa*		
14	*Karthika* (MO 7)	44	*Kavunginpoothala* (Ptb 15)		
15	*Lakshmi* (Kylm 1)	45	*Navara*		
16	*Makom* (MO 9)	46	*Pavizhachembavu*		
17	*Neeraja* (Ptb 47)	47	*Thrissur local-1* (P.K.9)		
18	*Nila* (Ptb 48)	48	*Ponnaryan* (Ptb 2)		
19	*Onam* (Kylm 3)	49	*Sinduram*		
20	*Pavizham* (MO 6)	50	*Thekken* (Ptb 21)		
21	*Red Triveni* (Ptb 45)	51	*Thekkencheera* (Ptb 10)		
22	*Remya* (MO 10)	52.	*Teena*		
23	*Reshmi* (Ptb 44)	53	*Vadakken Chitteni* (Ptb 20)		
24	*Sabari* (Ptb 40)	54	*Vellair* (Ptb 4)		
25	*Sagara*	55	*Veluthavattan* (Ptb 22)		
26	*Swarnaprabha* (Ptb 43)	56	*Veluthari Thavalakannan* (Ptb 9)		
27	*Swarnamodan* (Ptb 42)	57	*Thrissur local - 2* (0-10)		
28	*Triveni* (Ptb 38)	58	*Aranmula local* (12-90)		
29	*Vyttila - 1*				
30	*Vyttila - 3*				

Hybrid derivatives were procured from Rice Research Stations of Kerala Agricultural University located at Moncompu, Pattambi, Kayamkulam and Vyttila, CSRC Karamana and Instructional farm at Vellayani and Mannuthy from time to time during the course of work.

The traditional/local varieties were collected from Regional Agricultural Research Station, Pattambi and from progressive farmers.

The two other improved/market varieties were collected from progressive farmers in Thrissur District. Five to six kilograms each of the sixty varieties were processed into two types ie.raw milled and parboiled milled and the samples obtained after milling were stored in airtight metal containers for various laboratory studies.

3.2 QUALITY PARAMETERS

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

Under each parameter, a number of indicators are available. Among these parameters physical characteristics and cooking characteristics influence the consumers appeal immediately, while the organoleptic quality positively influences the popularity of the rice in the long run. Parameters like nutritional composition has little influence on the popularity of the rice varieties among consumers.

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

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) Thousand grain weight (Sidhu *et al*, 1975)

b) Grain dimension ratio (L/B Ratio) (Pillaiyar and Mohandoss, 1981c)

c) Moisture (A.O.A.C., 1960)

d) Head rice yield (Rajalakshmi, 1984)

3.2.2. Cooking characteristics

Cooking and processing qualities are major determinants of consumer preference and acceptance that ultimately decides eating quality. Different indicators ascertained under cooking characteristics are:-

a) Optimum cooking time (Bhattacharya and Sowbhagya, 1971)

b) Volume expansion (Pillaiyar and Mohandoss, 1981c)

c) Water uptake (Bhattacharya and Sowbhagya, 1971)

d) Gruel loss (Sanjiva Rao *et al.,* 1952)

e) Gelatinization temperature (Mac Masters, 1964)

f) Elongation ratio (Pillaiyar and Mohandoss, 1981c)

g) Elongation index (Sood and Siddiq, 1980) and

h) Viscosity (ISI, 1960).

3.2.3. Organoleptic qualities

Organoleptic qualities play an important role in evaluating the quality of a food product. For adjudging consumer acceptability, organoleptic evaluation of any food product is essential. Araullo *et al.*(1976) had observed that the palatability characteristic (appearance, colour, cohesiveness, tenderness and flavour) also contribute an important factor in grading the quality of rice. According to Ikehaski and Khush (1979) visual rating of the above traits had been the most important method to assess the organoleptic qualities of rice. The overall quality was evaluated by preparing different dishes using different cooking methods and evaluating its sensory qualities by scoring technique using a taste panel.

The different cooking methods selected and recipes prepared were.

a) Boiling method - cooked rice - raw and parboiled

b) Fermenting and steaming (Iddli)

c) Fermenting and shallow frying (Dosa)
d) Powdering, roasting and steaming (Puttu)
e) Powdering, roasting and boiling (Kozhukkatta)
f) Baking (Appam)

The panel members for sensory analysis were selected by conducting a Triangle test (Appendix I). The quality attributes of the products prepared were assessed using composite scoring test (IS : 1972). The major quality attributes scored by the panel members on a 5 point hedonic scale were appearance, colour, flavour, texture and taste (Appendix 2).

3.2.4. Nutritional composition

Nutritional composition is a major parameter influencing the quality of rice grains from the point of view of nutritionists. The major nutrients studied were calorific value (Energy) protein, starch, amylose, amylose-amylopectin ratio, crude fibre, ash content, phosphorus, iron and calcium.

Different indicators ascertained under nutritional composition are:-

a) Calorific value (Swaminathan, 1984)
b) Protein (Kjeldahls' method - Hawk and Oser, 1965)
c) Starch (Aminoff *et al.*, 1970)
d) Total amylose (Maccready and Hassid, 1943)
e) Amylose: Amylopectin ratio (Maccready and Hassid, 1943)
f) Crude fibre (Raghuramulu *et al.,* 1983)
g) Ash content (Raghuramulu *et al.,* 1983)
h) Phosphorus (Jackson, 1973)
i) Iron (Jackson, 1973)
j) Calcium (Jackson, 1973)

3.2.5. Statistical analysis

Analysis of variance was done for all the parameters like physical, cooking and organoleptic characteristics and nutritional composition. Correlation matrix was also worked out. Cluster analysis was performed for raw and parboiled rice varieties to group/cluster them based on quality attributes such as colour, appearance, flavour, texture and taste.

A measure for group distance based on multiple characters was given by Mahalanobis (1928). This method was applied by plant breeders to group/cluster the various genotypes based on multiple characters (Singh and Choudhary, 1985). This method is applied in the present study to cluster the rice varieties based on their physical, cooking characteristics and also organoleptic qualities.

The various steps involved in the estimation of D^2 values are listed below:-

1. Collection of data with respect to physical and cooking qualities for all the rice varieties.

2. Estimate the various variance among these characters with respect to varieties and error.

3. Test the simultaneous significance of mean differences among the varieties using the method of analysis of dispersion in respect of the pooled effect of these qualities.

4. The character/variables are then transformed into a set of uncorrelated variable using pivotal condensation method of the error variance - co-variance matrix.

5. Estimation of D^2 values using the transformed means is as follows:

   D^2 with respect to k^{th} and l^{th} varieties is given as

   $$D^2 = \Sigma_i \ (y_i^{(k)} - y_i^{(l)})^2 \text{ where}$$

   $y_i^{(k)} - y_i(l)$ is the difference in the mean values of character 'i' with respect to k^{th} and l^{th} varieties. As such with n varieties nc_2 distances are worked out.

6. The varieties are grouped based on their D^2 values using Tocher method (Rao, 1952)

7. The average inter and intra cluster distances are worked out.

8. A cluster diagram is drawn using the $\sqrt{D^2}$ values. This diagram is not exactly with scale.

Discriminant function of Fisher (1936) is used to define the merit of rice varieties used in this study on the basis of physical, cooking, organoleptic qualities and nutritional composition, in terms of an index which is defined as selection index by Smith (1937) who used this index to indicate the genetic worthiness of a plant based on observable characters.

The genetic worthiness of variety based on a characters is linearly expressed as

$$H = a_1 G_1 + a_2 G_2 + \ldots\ldots a_n G_n$$

where $a_1 + a_2 \ldots\ldots a_n$ are the economic weights assigned to each variable. This merit cannot be evaluated directly because only the phenotypic or observable values are measured. The phenotypic value is linearly expressed as

$$I = b_1 r_1 + \ldots\ldots\ldots b_n r_n$$

if n characters are involved.

The superiority of varieties using I as a discriminant function will ensure maximum gain provided the 'b' values are estimated in such a way that the correlation between I and H is maximum. The maximization of this correlation will yield to the simultaneous solution of a system of 'n' equations of the form.

$$\underline{X}\,\underline{b} = \underline{G}\,\underline{a}$$

where $\underline{X}$ and $\underline{G}$ stands respectively for the phenotypic and genotic variance - co-variance matrices and $\underline{b} = X^{-1}\,\underline{G}\,\underline{a}$

The mathematical description of I is known as selection index, this function will help to discriminate among the superior and inferior varieties. Those varieties with highest values are considered as superior ones.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The study entitled "A multi variate approach to define the quality of rice" was conducted to ascertain the following qualities of raw and parboiled rice varieties for developing a comprehensive index to define the quality of rice through a multivariate approach.

1. Physical characteristics
2. Cooking characteristics
3. Organoleptic characteristics and suitability for different rice preparations.
4. Cluster analysis
5. Nutritional composition and
6. Development of quality indices.

4.1 PHYSICAL CHARACTERISTICS

Major physical characteristics assessed were thousand grain weight, grain dimension ratio (L/B ratio), head rice yield and moisture content. Thousand grain weight and grain dimension ratio were determined in unhusked rice and all the four parameters were estimated in husked rice.

4.1.1. Thousand grain weight (unhusked) (Table 2 and Appendix 3)

Thousand grain weight is a major determinant in adjudging the popularity of rice varieties. Farmers prefer grains with a higher thousand grain weight.

Results obtained indicate that varietal variations and processing had a profound influence on this variable.

Thousand grain weight of different rice varieties (unhusked) were found to vary significantly. Among the sixty rice varieties (unhusked) the highest value was recorded for a hybrid variety *Reshmi* (33.20g) and the lowest value for an improved and popular variety *Mashuri* (18.50g). Considerable variation was found between hybrid derivatives and traditional varieties. Hybrid derivatives had a thousand grain weight range between 22.20g (*Makom*) and 33.20g (*Reshmi*) while traditional varieties had a range between

18.00g (*Kavunginpoothala*) and 31.00g (*Chuvannamodan*). For other improved varieties it ranged between 18.50g (*Mashuri*) and 20.80g (*CO-25*).

The mean value for thousand grain weight was higher (27.39g) for hybrid derivatives as compared to traditional (25.22g) and other improved varieties (19.65g).

Fifteen hybrid derivatives and fourteen traditional varieties and one other improved variety were found to have higher thousand grain weight than their mean values worked out.

A significant difference was also observed between the raw and parboiled samples. Parboiled samples had significantly higher thousand grain weight compared to raw samples. The hybrid derivatives were found to have higher thousand grain weight (28.11g) when compared to traditional (25.65g) and other improved varieties (20.30g). After parboiling the highest value was observed for *Reshmi* (34.60 g) and the lowest value for *Mashuri* (19.10g). Among parboiled hybrid derivatives the variation was in the range of 23.50 (*Jayathi*) to 34.60g (*Reshmi*) while in traditional varieties it was in the range of 19.00 (*Kavunginpoothala*) to 31.80g (*Chettivirippu*). In other improved varieties it was 19.10 (*CO-25*) to 21.50g (*Mashuri*).

The increase in thousand grain weight after parboiling might be due to the excess moisture absorbed during the process. Hybrid derivatives such as *Sagara, Reshmi, CSRC collection, Bhagya, Jaya* and traditional varieties such as *Chettivirippu, Kutticheradi* had the capacity to absorb more water during parboiling resulting in positive variation in physical dimension and a higher thousand grain weight in the parboiled state while varieties like *Annapoorna, Dhanya, Jayathi, Thekken, Ponnaryan, Elappapoochenban and Kattamodan* did not absorb much water during parboiling when compared to their raw form. Similar observations have been reported by Webb and Stermer (1972). However, Raghavendra Rao and Juliano (1970) have not observed any alteration in this variable due to parboiling.

The difference in thousand grain weight of raw and parboiled varieties was also worked out. In the case of hybrid derivatives, the maximum difference of 2.40g was found in the variety (*Sagara*) while the lowest difference of 0.07g was observed in the variety

Annapoorna. In the case of traditional varieties the maximum difference of 1.40g was found in the variety *Kutticheradi* and the lowest 0.05g was observed in the variety *Ponnaryan* and *Thekken.*

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 has been 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). Drought during the milking stage of the grains was also reported to decrease the weight of the grains (Dev, 1991).

Coarse varieties such as *Reshmi, Sabari and Vyttila-3* were found to have a higher thousand kernel weight when compared to fine varieties such as *Mashuri, CO-25 and Kavunginpoothala.* Similar observations have been recorded by Sidhu *et al.* (1975).

The data when analysed statistically revealed that there is significant interaction between the varieties and the processing with respect to thousand grain weight.

4.1.2 Grain dimension ratio (L/B ratio) (Table 2 and Appendix 4)

Physical dimensions of grain such as the length, breadth or width and the thickness as well as the shape of the kernel vary from variety to variety. These are considered to be important criteria of rice quality especially for developing new varieties for commercial production (Bandyopadhyay and Roy, 1992).

Length of the grain is measured in its greatest dimension, breadth or width along the ventral side and thickness across the dorsal side. The shape is determined by a ratio of two of the dimensions (length and width). Since the variation in thickness of grains is not considerable, the length: breadth ratio is used in classifying the shape of the grains.

The grain dimension ratio varied significantly between the varieties. In rice samples (unhusked), the grain dimension ratio was highest (4.29) for the variety *Aranmula local* while the lowest ratio (1.91) was observed for the variety *Bhadra.*

Table 2 Selected physical characteristics of rice varieties (Unhusked)

		Thousand grain weight (g)		L/B Ratio	
Sl. No.	Variety	Raw	Parboiled	Raw	Parboiled
(1)	(2)	(3)	(4)	(5)	(6)
Hybrid derivatives					
1	Annapoorna	25.98	26.05	3.24	3.04
2	Aruna	28.60	29.30	2.81	2.64
3.	Asha	30.50	31.20	2.08	1.92
4.	Bhadra	24.90	26.00	1.91	1.80
5.	Bharathy	29.50	30.00	3.35	3.28
6.	Bhagya	24.90	26.90	2.88	2.73
7.	CSRC collection	22.70	25.00	2.82	2.65
8.	Dhanya	25.30	25.50	2.58	2.45
9.	Hraswa	24.00	24.80	2.67	2.49
10.	Jaya	29.70	30.80	3.29	3.10
11.	Jayathi	23.20	23.50	2.49	2.32
12.	Jyothi	30.00	30.30	3.40	3.26
13.	Kanakom	25.90	26.80	2.95	2.77
14.	Karthika	27.30	28.00	3.21	3.01
15.	Lakshmi	26.50	26.70	2.97	2.72
16.	Makom	22.20	23.50	2.81	2.64
17.	Neeraja	23.50	24.00	3.05	2.82
18.	Nila	28.70	29.20	2.43	2.31
19.	Onam	27.50	28.20	3.45	3.18
20.	Pavizham	23.10	24.00	2.66	2.50

(1)	(2)	(3)	(4)	(5)	(6)
21.	Red Triveni	28.00	28.80	2.67	2.49
22.	Remya	30.20	30.50	3.55	3.18
23.	Reshmi	33.20	34.60	2.01	1.87
24.	Sabari	32.70	33.00	3.39	3.22
25.	Sagara	30.60	33.00	2.72	2.60
26.	Swarnaprabha	28.00	28.60	2.50	2.39
27.	Swarnamodan	23.15	23.90	3.24	2.92
28.	Triveni	25.25	25.75	2.64	2.49
29.	Vyttila-1	31.60	31.75	3.20	3.09
30.	Vyttila-3	32.80	33.00	3.05	2.91
	Mean	**27.39**	**28.11**	**2.89**	**2.69**
Traditional / local varieties					
31.	Aruvakkari	25.00	25.75	2.63	2.45
32.	Aryankali	28.40	28.70	2.59	2.50
33.	Aryan	24.00	24.50	2.82	2.68
34.	Chenkayama	23.00	23.30	2.59	2.49
35.	Cheriya Aryan	22.65	22.80	2.64	2.54
36.	Chettivirippu	30.50	31.80	3.31	3.17
37.	Chitteni	28.00	28.35	2.67	2.59
38.	Chuvannamodan	31.00	31.55	2.83	2.74
39.	Chuvannari Thavalakannan	23.10	23.45	2.50	2.36
40.	Elappapoochemban	23.65	23.75	2.45	2.37
41.	Kattamodan	25.60	25.70	2.70	2.54
42.	Kutticheradi	29.80	31.20	3.14	3.00

(1)	(2)	(3)	(4)	(5)	(6)
43.	Kuruwa	25.60	26.40	2.96	2.74
44.	Kavunginpoothala	18.00	19.00	3.56	3.33
45.	Navara	22.50	22.70	2.91	2.75
46.	Pavizhachembavu	24.70	24.90	2.94	2.72
47.	Thrissur local -1	25.40	25.60	3.16	2.98
48.	Ponnaryan	25.85	25.90	2.95	2.80
49.	Sinduram	24.90	25.90	3.16	2.98
50.	Thekken	25.65	25.70	2.84	2.67
51.	Thekkencheera	22.35	22.45	2.80	2.62
52.	Teena	24.10	24.30	3.25	2.86
53.	Vadakken Chitteni	27.00	27.25	2.77	2.67
54.	Vellari	28.00	28.15	2.64	2.55
55.	Veluthavattan	22.10	22.20	2.77	2.61
56.	Veluthari Thavalakannan	22.75	22.90	2.54	2.49
57.	Thrissur local - 2	25.40	25.80	2.96	2.81
58.	Aranmula local	27.20	28.00	4.29	4.02
	Mean	**25.22**	**25.65**	**2.91**	**2.75**
Other improved/market varieties					
59.	CO-25	20.80	21.50	2.45	2.22
60.	Mashuri	18.50	19.10	3.18	2.75
	Mean	**19.65**	**20.30**	**2.82**	**2.49**
	Gross Mean	**26.08**	**26.69**	**2.88**	**2.71**
	CD values				
	Varieties	0.616		0.070	
	Processing	0.113		0.013	
	Variety x Processing	0.872		0.099	

The comparison further revealed that traditional varieties had higher grain dimension ratio (2.91) in the range of 2.45 to 4.29 when compared to hybrid derivatives (2.89) in the range of 1.91 to 3.55. For other improved varieties the L/B ratio ranged between 2.45 to 3.18.

The highest ratio was observed for the variety *Aranmula local* (4.29), *Remya* (3.55) and *Mashuri* (3.18) for traditional, hybrid and other improved/market varieties respectively while the lowest ratio was noticed in *Elappapoochemban* (2.45), *Bhadra* (1.91), *CO-25* (2.45) in the above three groups.

A significant difference in the grain dimension ratio was noticed after parboiling. The grain dimension ratio was found to be decreased in all the parboiled rice samples (unhusked) when compared to raw samples. Parboiling process increased the dorsi - ventral diameter of the grains and this might be one of the reasons for the reduction in the L/B ratio during parboiling. Raghavendra Rao and Juliano (1970) have reported similar findings.

A comparative study of different varieties of parboiled rice samples (unhusked) revealed that traditional varieties had higher L/B ratio (2.75) in the range of 2.36 to 4.02 when compared to hybrid derivatives (2.69) and other improved varieties (2.49) having an L/B ratio in the range 1.80 to 3.28. In other improved varieties, L/B ratio ranged from 2.22 to 2.75.

The highest ratio was observed for the varieties *Aranmula local* (4.02), *Bharathy* (3.28) and *Mashuri* (2.75) in the case of traditional, hybrid and other improved varieties respectively while the lowest ratio was noticed for *Chuvannari Thavalakannan* (2.36), *Bhadra* (1.80) and *CO-25* (2.22) in the above three groups. The interaction between varieties and the effect of processing was also found to be statistically significant.

4.1.3 Thousand grain weight (husked) Table 3 and Appendix 3)

Observations recorded indicate a similar trend as already discussed for rice samples (unhusked).

All the husked samples were observed to have lower values than (unhusked) rice samples.

Similar to (unhusked) rice the thousand grain weight of rice samples (husked) also varied considerably between hybrid derivatives and traditional varieties. Hybrid derivatives were found to have higher values (20.96g) than the traditional (19.93g) and other improved varieties (15.65g).The variation was in the range of 15.60 to 26.30g among hybrid derivatives while it was 15.10 to 23.40g in traditional varieties. In other improved varieties it was found to be 15.30 to 16.00g. The highest value was observed for *Reshmi, Chettiviripp*u and *CO-25* among hybrid, traditional and other improved varieties respectively while the lowest value was noticed for *Red Triveni*, *Kavungin poothala* and *Mashuri* in the above three groups.

As observed in (unhusked) rice samples, a significant difference was also noticed between raw and parboiled samples when they were subjected to dehusking. In general, parboiled samples had a significantly higher value than the raw samples. Parboiled hybrid derivatives were found to have higher values (21.86g)when compared to traditional varieties (20.92g) and other improved varieties (16.25g). However, unlike in rice samples, (unhusked) in hybrid derivatives the highest value was obtained for the variety *Reshmi* and the lowest value was recorded for the variety *Kavunginpoothala*.

A comparison of different varieties of parboiled rice samples revealed that the variation was in the range of 15.90 to 26.55g in the case of hybrid derivatives followed by traditional varieties (15.30 to 23.90g). In other improved varieties it ranged between 15.60 to 16.90g.

The highest value for thousand grain weight was again observed in *Reshmi, Chettiviripp*u, *Chuvannamodan* and *CO-25* in the case of hybrid, traditional and other improved varieties respectively while the lowest value was noticed in *Red Triveni, Kavunginpoothala* and *Mashuri* in the above three respective groups.

A comparison among the different types of rice (unhusked) and rice varieties (husked) processed by two methods (raw milled and parboiled milled) indicated significant variations among different (husked) rice varieties and processed samples revealing the influence of these two variables on thousand grain weight. Similar results were obtained for the same variety of rice (unhusked) when processed.

Compared to rice samples, (unhusked) variation in thousand grain weight of husked rice samples were in the range of 0.20 (*Karthika*) to 2.20g (*Dhanya*) in the case of hybrid derivatives, followed by traditional varieties in the range of 0.10 (*Thekkencheera*) to 2.80g (*Aranmula local*). In other improved varieties it ranged between 0.30 (*Mashuri*) to 0.90g (CO-25).

Significant variations in thousand grain weight observed earlier in coarse and fine (unhusked) rice varieties were also noticed in the (husked) rice samples.

An important point to be noted, while ascertaining the quality or rice grain is the quantum of wastage that occurs during dehusking.

The differences in thousand grain weight between unhusked and husked samples of sixty rice varieties were also worked out. In the case of raw samples, the mean values were found to be higher in hybrid derivatives (6.30g) when compared to traditional (5.5g) and other improved varieties (4.00g) and this might be due to higher percentage of chaff, bran and other substances in hybrid derivatives. In the case of hybrid derivatives (raw samples) the mean value was found to be 6.30g (in the range of 1.70 to 12.40g). Greater losses occurred in rice varieties such as *Annapoorna* (8.18g), *Asha* (7.50g), *Lakshmi* (7.00g), *Bharathy* (9.30g), *Jaya* (8.80g), *Kanakom* (8.00g), *Sabari* (7.30g), *Vyttila-1* (7.00g) and *Red Triveni* (12.40g). In traditional varieties the mean value was found to be 5.51g (in the range of 0.95 to 9.90g). Greater losses among the traditional varieties studied occurred in the rice grains of varieties such as *Aruvakkari* (9.90g), *Aryankali* (8.10g), *Chettivirippu* (7.10g) *Chuvannamodan* (8.20g), *Kutticheradi* (8.00g), *Thrissur local-1* (7.30g), *Thekken* (8.25g), *Vellari* (7.60g), and *Aranmula local* (8.90g). After parboiling the mean values were 6.18g (2.65-8.70g) and 4.72g (0.95-8.70g) respectively in hybrid derivatives and traditional varieties which indicates that the process of parboiling significantly reduces losses during milling.

Based on thousand grain weight, FAO (1970) has classified rice grains(husked) into three categories such as:

Extra bold - weight of 25g and above
Bold - weight between 20 to 25g
Medium bold - weight less than 20g

The varieties included in each group were as follows:-

	Extra bold	Bold	Medium bold
Hybrid derivatives	*Reshmi, Remya, Sabari , Vyttila-3 and Sagara*	*Aruna, Asha, Bharathy, Bhagya, Hraswa, Jaya, Jyothi, Karthika, Makom, Swarnaprabha, Nila, Onam and Vyttila-1*	*Annapoorna, Bhadra, Dhanya, CSRC-collection, Jayathi, Kanakom, Lakshmi, Neeraja, Pavizham, Red-Triveni, Swarnamodan and Triveni.*
Traditional/ local varieties		*Aruvakkari, Aryankali, Aryan, Chenkayama, Cheriya Aryan, Chettivirippu, Chitteni, Chuvannamodan, Elappapoochembon, Kattamodan, Kuruwa Kutticheradi, Thekkencheera, Vadakken Chitteni and Vellari*	*Chuvannari-Thavalakannan, Kavunginpoothala, Navara, Pavizha-chembavu, Trissur-local-1, Ponnaryan, Sinduram, Thekken, Teena, Veluthavattan, Veluthari-Thavalakannan, Thrissur local-2 and Aranmula local*
Other improved/ market varieties			*CO-25 and Mashuri*

Out of the sixty varieties studied only five were under the extra bold category and all of them are hybrid derivatives.

The data when analysed statistically revealed that there is significant interaction between the varieties and processing with respect to thousand grain weight.

4.1.4 Grain dimension ratio (L/B ratio) (Table 3 and Appendix 4)

The results revealed a similar trend as reported in the present study under rice samples (unhusked).

All the (husked) rice samples were noticed to have lower values than (unhusked) rice samples because of the removal of husk and bran during milling.

Unlike (unhusked) rice the L/B ratio of (husked)rice also varied considerably between hybrid derivatives and traditional varieties. The L/B ratio of different rice varieties (husked) were found to be same for hybrid derivatives and traditional varieties (2.26). The variation was in the range of 1.65 *(Pavizham)* to 2.85 *(Neeraja)* within hybrid derivatives while it was 1.78 *(Chitteni)* to 3.15 *(Aranmula local)* in traditional varieties. In other improved varieties it was found to be between 2.24 *(CO-25)* to 2.50 *(Mashuri)*.

Similar to (unhusked) rice samples, a significant difference was also noticed among the two processing methods. In general, parboiled samples had a significantly lower value when compared to raw samples due to increase in the dorsi-ventral diameter of the grains. But parboiled traditional varieties were found to have higher values (2.17) when compared to hybrid derivatives (2.13). Unlike (unhusked) rice samples, in traditional varieties, the highest value of 2.93 was observed for the variety *Aranmula local* and the lowest value was for the variety *Chitteni* (1.76).

A comparison among parboiled samples revealed that they exhibited a variation in the range of 1.76 *(Chitteni)* to 2.93 *(Aranmula local)* in the case of traditional varieties followed by hybrid derivatives in the range of 1.55 *(Reshmi)* to 2.68 *(Neeraja)*. In other improved varieties it ranged between 2.18 *(CO-25)* to 2.40 *(Mashuri)*.

Table 3 Selected physical characteristics of rice varieties (Husked)

Sl. No.	Variety	Thousand grain weight(g) Raw	Thousand grain weight(g) Parboiled	L/B Ratio Raw	L/B Ratio Parboiled	Head rice yield (%) Raw	Head rice yield (%) Parboiled	Moisture(%) Raw	Moisture(%) Parboiled
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Hybrid derivatives									
1.	Annapoorna	17.80	19.60	2.77	2.30	26.36	37.06	12.62	11.67
2.	Aruna	22.60	23.00	1.98	1.94	35.50	50.50	13.00	11.67
3.	Asha	23.00	23.60	2.14	2.06	35.50	55.50	13.25	12.00
4.	Bhadra	18.10	19.00	2.02	1.92	42.00	46.50	14.00	11.76
5.	Bharathy	20.20	21.30	2.69	2.30	23.60	74.25	11.67	12.28
6.	Bhagya	22.10	23.20	2.38	2.35	28.00	57.00	13.67	12.33
7.	CSRC collection	19.80	21.00	2.26	2.26	26.50	36.00	13.50	12.33
8.	Dhanya	19.60	21.80	1.82	1.77	38.00	45.50	16.17	12.00
9.	Hraswa	20.20	20.80	2.31	2.26	60.50	71.72	13.69	11.29
10.	Jaya	20.90	22.10	2.15	2.02	38.00	42.00	13.33	12.67
11.	Jayathi	16.60	17.70	1.89	1.77	21.47	69.46	12.29	11.20
12.	Jyothi	23.50	24.60	2.59	2.31	31.00	39.00	13.17	12.62
13.	Kanakom	17.90	18.50	2.33	2.26	39.50	55.00	13.17	12.67
14.	Karthika	21.60	21.80	2.80	1.90	29.00	33.50	14.25	14.22
15.	Lakshmi	19.50	20.20	1.98	1.90	37.00	46.50	12.00	11.67
16.	Makom	20.50	20.85	2.54	2.44	39.00	46.00	13.50	11.33
17.	Neeraja	17.70	18.60	2.85	2.68	46.02	67.56	11.59	12.67
18.	Nila	21.90	23.10	1.78	1.70	18.65	45.84	11.67	11.56
19.	Onam	22.60	24.00	2.66	2.49	36.00	43.00	14.33	12.92
20.	Pavizham	17.50	18.55	1.65	1.72	42.00	53.00	13.00	12.26
21.	Red Triveni	15.60	15.90	1.81	1.81	37.00	44.00	14.00	12.81
22.	Remya	25.20	25.70	2.60	2.50	39.50	45.00	13.50	12.00

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
23.	Reshmi	26.30	26.55	1.69	1.55	20.12	31.58	13.07	12.73
24.	Sabari	25.40	25.65	2.70'	2.57	37.50	47.00	14.00	12.00
25.	Sagara	25.40	26.15	1.97	1.90	28.00	56.50	14.33	11.44
26.	Swarnaprabha	22.30	22.75	2.32	2.24	28.35	37.25	11.67	11.67
27.	Swarnamodan	17.60	18.35	2.36	2.27	47.20	53.47	11.00	12.55
28.	Triveni	18.30	20.10	2.09	2.00	18.80	27.72	12.32	11.49
29.	Vyttila-1	24.60	26.50	2.48	2.33	34.60	92.24	10.33	16.67
30.	Vyttila - 3	26.10	26.35	2.37	2.23	67.96	90.78	9.33	10.01
	Mean	**20.96**	**21.86**	**2.26**	**2.13**	**35.09**	**51.35**	**12.91**	**12.22**
Traditional/ local varieties									
31.	Aruvakkari	21.10	22.20	2.36	2.29	34.18	35.62	13.02	11.38
32.	Aryankali	20.30	21.20	2.06	1.98	30.50	59.00	13.50	13.00
33.	Aryan	21.40	22.30	2.25	2.17	49.24	63.95	11.33	12.01
34.	Chenkayama	21.10	21.40	1.94	1.87	40.68	69.08	12.00	12.47
35.	Cheriya Aryan	20.10	20.40	2.04	1.97	32.22	68.36	13.08	12.86
36.	Chettivirippu	23.40	23.90	2.50	2.36	33.50	43.50	14.00	13.58
37.	Chitteni	21.30	22.20	1.78	1.76	35.60	51.58	14.00	13.67
38.	Chuvannamodan	22.80	23.90	2.17	2.02	39.00	67.25	11.00	13.33
39.	Chuvannari Thavalakannan	19.40	21.10	1.99	1.94	68.72	81.32	12.87	10.69
40	Elappapoochemban	20.20	20.75	2.19	2.11	39.78	74.16	11.00	12.36
41.	Kattamodan	21.30	22.80	1.98	1.93	55.51	55.80	11.67	13.11
42.	Kutticheradi	21.80	22.50	2.40	2.29	36.22	74.20	13.04	13.36
43.	Kuruwa	20.50	21.10	2.06	1.90	21.00	52.00	16.33	12.67
44.	Kavunginpoothala	15.10	15.30	2.80	2.71	18.15	65.00	11.33	12.68
45.	Navara	16.90	18.20	2.16	2.15	41.38	55.25	12.75	11.70

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
46.	Pavizhachembavu	18.70	20.40	2.33	2.25	26.00	52.50	14.00	13.67
47.	Thrissur local -1	18.10	18.60	2.33	2.23	28.20	31.86	13.51	13.33
48.	Ponnaryan	19.80	20.80	2.13	2.05	47.20	59.40	14.29	13.67
49.	Sinduram	19.00	19.70	2.40	2.27	37.64	82.10	13.33	13.00
50.	Thekken	17.40	20.00	2.20	2.15	19.82	69.35	11.67	13.91
51.	Thekkencheera	21.40	21.50	2.47	2.38	32.58	48.18	13.02	13.08
52.	Teena	19.10	20.10	2.60	2.64	22.50	60.50	13.67	13.12
53.	Vadakken Chitteni	20.80	22.30	2.18	2.12	49.40	60.50	12.00	11.48
54.	Vellari	20.40	21.30	2.09	2.00	45.25	62.97	13.33	12.33
55	Veluthavattan	19.70	20.30	1.91	1.81	41.25	58.04	12.33	12.81
56.	Velluthari Thavalakannan	19.80	20.35	1.96	1.89	59.62	71.96	14.09	13.67
57.	Thrissur local - 2	18.70	20.00	2.32	2.15	19.80	48.20	13.19	13.02
58.	Aranmula local	18.30	21.10	3.15	2.93	38.00	42.00	14.00	14.66
	Mean	**19.93**	**20.92**	**2.26**	**2.17**	**38.05**	**62.34**	**12.98**	**12.81**
Other improved/market varieties									
59.	CO- 25	16.00	16.90	2.24	2.18	22.46	81.94	12.00	12.69
60.	Mashuri	15.30	15.60	2.50	2.40	52.14	76.42	12.87	11.20
	Mean	**15.65**	**16.25**	**2.37**	**2.28**	**37.30**	**79.18**	**12.44**	**11.95**
	Gross Mean	**20.33**	**21.26**	**2.26**	**2.15**	**36.19**	**56.01**	**12.93**	**12.42**
	CD values								
	Varieties	0.092		0.126		5.178		0.089	
	Processing	0.017		0.023		0.945		0.016	
	Variety x processing	0.131		0.178		7.323		0.125	

A significant interaction was also found between varieties and processing.

However classification in trade and commerce is based on length instead of thousand grain weight. Thus it is classified as Extra long (length more than 7 mm), Long (length 6.0 to 7.0mm), Medium (length 5.5 to 5.9mm) and short (length less than 5.5mm) (FAO, 1970).

In the present study, four varieties belonged to the group extra long and there were eleven varieties in the group long, twenty two varieties in the group medium and twenty three varieties in the group short.

Based on shape, the rice varieties were divided into four groups viz., Slender (L/B ratio more than 3.0), Medium (L/B ratio between 2.4 to 3.0), Bold (Coarse) (L/B ratio between 2.0 to 2.39) and Round (L/B ratio below 2.0) (FAO, 1970).

In this study only one variety was found under group Slender while sixteen varieties could be grouped as Medium, thirty varieties as Bold and thirteen varieties as Round.

4.1.5 Head rice yield (Table 3 and Appendix 3)

Head rice yield is the yield of whole rice after milling of paddy (Rajalakshmi, 1984). Higher the percentage of head rice yield, lesser will be the percentage of brokens.

A significant difference in the percentage of head rice yield was noticed among the different rice varieties. Head rice yield was higher in traditional varieties (38.05 per cent) than that of hybrid derivatives (35.09 per cent) and other improved varieties (37.30 per cent) in raw samples.

A comparison among raw varieties, revealed that traditional varieties had a head rice yield in the range of 18.15 per cent *(Kavunginpoothala)* to 68.72 per cent *(Chuvannari Thavalakannan)* while the hybrid derivatives had a range of 18.65 per cent *(Nila)* to 67.96 per cent *(Vyttila-3)*. In the case of other improved varieties the head rice yield ranged between 22.46 per cent *(CO- 25)* to 52.14 per cent *(Mashuri)*.

Direct sundrying of paddy varieties was found to result in lower head rice yield when compared to mechanical drying (Dev, 1991). In sun-drying uncontrolled non-uniform drying results in sun checks or cracks in kernels and subsequent breakage during milling. This might be one of the causes for the wide variation in the head rice yield.

In Kerala, varieties harvested in the Mundakan season such as *Nila, Kuruwa, Kavungin poothala, Thekken, and Thrissur local-1* were reported to have lower head rice yield. Head rice recovery was found to be low at early and late maturity stages (Ali *et al.*, 1993).

Head rice yield was also found to be influenced by the length of the grains. Long grained samples of rice such as *Jyothi, Onam and Sabari* gave significantly lower yields of head rice than short or medium grained samples such as *Hraswa, Kattamodan and Veluthari Thavalakannan.* Anon.(1961) and Goodman and Rao (1985) and Yadav *et al.* (1989) had reported similar observations. High variability in head rice yield within and between varieties was observed probably because of the above reasons. Findings of Sharma and Bains (1979) and Sidhu *et al.* (1975) support these observations. Ali *et al.* (1992) had observed that split application of nitrogen fertilizer produced significantly higher head rice recovery.

The head rice yield is reported to be influenced by kernel size, shape and moisture of the grains and time of harvesting (Tomar, 1981 and Geng, 1987). Tomar had further stated that at moisture level of 10 to 14 per cent, head rice yield (3.00 per cent) and total yields (0.70 per cent) increased for each one per cent decrease in rice moisture. A decreased head rice yield can be expected when rice is harvested at temperatures above 32°C.

Parboiling significantly increases head rice yield of all the rice varieties probably due to the changes in the process of hardening of the endosperm of the grain. Similar observations were reported by Rajalakshmi in 1984 and Mishra *et al* in 1986. A pre treatment method of soaking during parboiling is reported to increase the head rice yield (Bandyopadhyay and Roy, 1992). Other improved parboiled varieties were found to have better head rice yield of 79.18 per cent when compared to hybrid derivatives (51.35 per cent) and traditional varieties (62.34 per cent). Consumers prefer varieties with higher head rice yield because they give whole grains of uniform size and shape with no loss as "brokens".

A comparison of different varieties parboiled rice samples revealed that traditional varieties had a head rice yield in the range of 31.86 per cent (*Thrissur local-1*)to 82.10 percent *(Sinduram)* followed by hybrid derivatives in the range of 31.58 per cent *(Reshmi)* to 92.24 per cent *(Vyttila-1)*. In other improved varieties the head rice yield ranged from 76.42 per cent *(Mashuri)* to 81.94 per cent *(CO-25)*.

The data statistically analysed revealed that the interaction between varieties and processing was also significant.In the present study head rice yield had a significant positive correlation with optimum cooking time (r = 0.435**) and significant negative correlation with water uptake (r = -0.391**), volume expansion (r = -0.373**),gruel loss (r = -0.382**) and moisture (r = -0.164**) (Appendix 6).

4.1.6 Moisture (Table 3 and Appendix 3)

Moisture content is one of the most important factors which greatly affects the shelf life and milling quality of rice.

The moisture content of a product is represented either on the 'wet basis' (w.b) or on the the 'dry basis' (d.b) and is expressed in percentage.

Moisture content of rice is a very important factor which markedly affects several facets of rice quality viz.,(1) to decide whether the grain should be dried before storage or shipment (ii) for grading under ISI specifications (iii) for controlling the quality of rice to be used in dry breakfast cereals, parboiling and other processed foods containing rice.

The moisture content was found to be higher in traditional varieties (12.98 per cent) when compared to hybrid derivatives (12.91 per cent) and other improved varieties (12.44 per cent). In hybrid derivatives the moisture content was in the range of 9.33 to 16.17 per cent while in traditional varieties it was in the range of 11.00 to 16.33 per cent. In other improved varieties it ranged from 12.00 to 12.87 per cent. Highest moisture content was observed in *Kuruwa* (16.33 per cent), *Dhanya* (16.17 per cent) and *Mashuri* (12.87 per cent) in the case of traditional, hybrid and other improved varieties respectively while the lowest value was noticed in *Chuvannamodan* and *Elappapoochempan* (11.00 per cent), *Vyttila-3* (9.33 per cent)and *CO-25* (12.00 per cent) in the above three respective groups.

A significant decrease in moisture content was observed in parboiled rice samples when compared to raw samples. A slight decrease in moisture content after parboiling was also reported by Luh (1980). In the current study in parboiled samples the moisture content ranged from 10.01 to 16.67, 10.69 to 14.66 and 11.20 to 12.69 per cent respectively in the case of hybrid, traditional and other improved varieties. Highest moisture content was observed in *Vyttila-1* (16.67 per cent), *Aranmula local* (14.66 per cent) and *CO-25* (12.69 per cent) in the case of hybrid, traditional and other improved varieties where as the lowest moisture content was noticed in *Vyttila-3* (10.01 per cent), *Chuvannari Thavalakannan* (10.69 per cent) and *Mashuri* (11.20 per cent) respectively.

The data analysed revealed that the interaction between varieties and processing was significant with respect to moisture content.

4.1.7. Salient findings

Among the various indicators studied under physical characteristics, a higher value for thousand grain weight, grain dimension ratio and head rice yield and a lower value for moisture content depicts a better quality score for the grain.

A comparison among hybrid derivatives and traditional varieties revealed that varieties such as *Hraswa, Remya, Vyttila-1, Vyttila-3, Bharathy* under hybrid derivatives and varieties such as *kutticheradi, Kuruwa, Elappapoochemban, Sinduram, Veluthari Thavalakannan, Chuvannari Thavalakannan, Aryan and Chenkayama* under traditional varieties satisfy this requirements. The above mentioned varieties were found to have favourable values for the four indicators mentioned earlier.

Process of parboiling is also observed to have a positive effect on thousand grain weight and head rice yield and negative effect on L/B ratio and moisture.

Among the various indicators studied under physical characteristics, thousand grain w eight and L/B ratio were found to be the two major determinants of the quality of rice samples since they were not much influenced by other indicators identified under physical characteristics. In different varieties of rice such as *Jyothi, Remya, Onam, Hraswa, Sabari, Vyttila-3, Vyttila-1, Chettivirippu, Kutticheradi, Thekkencheera, Vadakken Chitteni, Elappapoochemban, Chuvannamodan* and *Aruvakkari,* size of the g rain was found to be mainly decided by the thousand grain weight. These determinants were also found to have a positive effect on the grain size either in raw or in parboiled form.

In Kerala, from consumers' point of view, grain size is a major consideration. Preference for parboiled rice by Keralaites may also be due to their affinity for extra bold or bold grains. Compared to traditional varieties, hybrid derivatives evolved through breeding programme, in general, satisfies this requirement better indicating its superiority over traditional varieties. A detailed analysis among the three categories of rice studied, show that hybrid derivatives are influenced to a greater extent by these indicators positively (thousand grain weight and L/B ratio). During parboiling process, the original grain dimension ratio were found to be retained only in a few varieties like *Red Triveni, Navara, Chitteni and CSRC collection.*

4.2 COOKING CHARACTERISTICS OF DIFFERENT RICE VARIETIES.

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

4.2.1 Optimum cooking time (Table 4 (a) and Appendix 5)

Certain cooking, eating and processing qualities of rice are essentially needed in Tropical Asia where as a majority of the population depend on rice as staple food (Juliano, (1967).

There was wide variation in optimum cooking time among different varieties of rice as shown in Table 4(a). The other improved varieties took less time to get cooked (22.75 min) when compared to traditional varieties (29.50 min) and hybrid derivatives (30.53 min.) Time taken by other improved varieties ranged from 22.50 to 23.00min while in the case of traditional varieties it ranged from 19.50 to 42.50 min. In hybrid derivatives the range was between 21.00 to 46 min. Lowest cooking time was noticed for the variety *Cheriya Aryan* (19.50 min.), *Jaya* (21.00 min) and *Mashuri* (22.50 min) in the case of traditional, hybrid and other improved varieties respectively.

A significant increase in the optimum cooking time was noticed in all the rice varieties after parboiling, probably because the rate of hydration and consequent gelatinization during cooking was slower than in the case of raw rice resulting in a longer cooking time. Priestley (1976a) and Sreedevi (1989) have also reported similar observations. Similar to raw rice, among parboiled rice samples, traditional varieties took less time to cook (48.14 min.) when compared to hybrid derivatives (50.18 min).

After parboiling the optimum cooking time was in the range of 32.50 min *(Elappapoochemban)* to 60 min *(Aranmula local)* in the case of traditional varieties whereas in hybrid derivatives it was in the range of 35.50 min *(kanakom)* to 65 min *(Vytilla-3)* and in the range of 34.50 min *(Mashuri)* to 45.50 min *(CO-25)* in other improved varieties.

The data also revealed that the interaction between varieties and processing was also significant with respect to cooking time.

It was further found that cooking time, gelatinization temperature (r = 0.182**) and thousand grain weight of milled rice (r = 0.294**) were positively correlated (Appendix 6). Similar observations were also reported by Juliano (1967). A negative correlation of optimum cooking time with gruel loss (r = -0.514**) and moisture (r = -0.155**) were also noticed in the present study (Appendix 6). It was noticed that the cooking time had a positive effect on protein content of varieties such as *Bhadra, Aruna, Bhagya,* and *Nila*. Findings of Govindaswamy and Ghosh (1970) support these observations.

Cooking time is one of the major determinants of the quality of rice grains and consumers prefer rice grains with less cooking time. Among the sixty rice varieties, 14 traditional varieties, 18 hybrid derivatives and one other improved variety took less time to cook when compared to the mean worked out.

4.2.2 Gruel loss (Table 4 (a) and Appendix 5)

The loss of Carbohydrates, principally starch and non-starch polysaccharides and lipids through the gruel is termed as gruel loss.

Table - 4 (a) Selected cooking characteristics of rice varieties

Sl. No.	Variety	Optimum cooking time (minutes)		Gruel loss (per cent)		Gelatinization-temperature (°C)		Viscosity (NSm^{-2})	
		Raw	Parboiled	Raw	Parboiled	Raw	Parboiled	Raw	Parboiled
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Hybrid derivatives									
1.	Annapoorna	21.50	50.50	6.00	2.50	87.00	91.00	1.98	2.32
2.	Aruna	30.50	44.50	9.50	5.00	87.50	86.50	2.14	2.21
3.	Asha	29.50	53.50	8.50	3.25	90.75	93.00	2.57	1.90
4.	Bhadra	32.00	64.50	3.00	2.50	95.50	93.50	2.50	1.97
5.	Bharathy	30.50	50.00	3.00	2.75	94.50	93.50	2.58	2.10
6.	Bhagya	46.00	50.50	9.25	2.00	85.50	86.50	1.90	1.91
7.	CSRC collection	43.00	62.50	4.65	3.00	91.00	92.50	2.14	2.87
8.	Dhanya	34.00	47.50	4.75	3.50	85.50	84.50	2.36	2.57
9.	Hraswa	34.00	47.50	10.50	3.00	85.50	85.50	2.28	2.34
10.	Jaya	21.00	46.00	4.65	3.25	86.00	93.50	2.50	2.35
11.	Jayathi	21.50	43.50	6.75	4.50	74.50	85.50	2.07	2.32
12.	Jyothi	37.00	46.00	3.25	2.00	83.50	87.00	2.62	2.96
13.	Kanakom	29.50	35.50	8.50	2.00	91.50	89.50	2.08	2.56
14.	Karthika	26.00	57.50	9.50	2.50	91.50	91.50	3.30	2.15
15.	Lakshmi	20.50	50.50	8.75	5.00	81.50	82.50	2.42	2.57
16.	Makom	25.50	45.00	6.75	3.50	92.50	93.50	1.94	1.97
17.	Neeraja	29.50	41.00	3.50	2.25	75.50	76.50	2.37	2.78
18.	Nila	37.00	46.50	5.50	3.75	75.50	75.50	2.18	2.33
19.	Onam	33.50	61.50	8.50	4.50	91.50	92.50	2.97	2.37
20.	Pavizham	25.50	45.00	4.25	4.50	90.50	91.50	3.11	2.35
21.	Red Triveni	25.50	52.50	6.50	4.50	90.50	90.50	2.54	2.73

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
22.	Remya	25.00	42.50	11.25	5.50	94.50	94.50	2.03	2.16
23.	Reshmi	23.50	63.00	6.75	2.50	85.00	84.50	1.97	2.09
24.	Sabari	33.00	53.50	7.65	5.00	84.50	82.50	1.97	2.09
25.	Sagara	33.00	37.00	7.50	5.50	86.00	86.50	2.09	2.17
26.	Swarnaprabha	30.50	39.50	4.50	3.25	87.50	86.50	2.01	2.15
27.	Swarnamodan	30.50	41.00	4.75	3.75	75.50	83.50	2.97	3.21
28.	Triveni	28.00	63.00	2.50	2.00	85.50	93.50	2.20	2.32
29.	Vyttila-1	42.50	64.50	7.75	3.25	85.00	85.00	2.95	2.03
30.	Vyttila-3	43.50	65.00	8.25	3.75	85.50	93.50	3.05	3.07
	Mean	**30.53**	**50.18**	**6.55**	**3.35**	**86.54**	**88.20**	**2.39**	**2.56**
Traditional/local varieties									
31.	Aruvakkari	22.00	37.00	10.75	6.50	77.00	78.50	2.07	2.45
32.	Aryankali	32.00	53.50	6.50	3.00	87.50	87.50	2.93	3.05
33.	Aryan	27.00	42.00	4.25	3.00	83.50	83.00	2.40	2.49
34.	Chenkayama	35.50	59.00	8.00	4.00	86.00	86.00	1.97	1.98
35.	Cheriya Aryan	19.50	37.50	10.75	4.00	83.50	85.50	2.08	2.51
36.	Chettivirippu	29.50	59.50	11.50	7.00	83.50	82.50	2.10	2.30
37.	Chitteni	42.50	56.50	9.75	4.75	78.50	79.50	2.13	2.37
38.	Chuvannamodan	27.00	38.50	9.75	5.00	86.50	89.50	2.32	2.95
39.	Chuvannari - Thavalakannan	28.50	46.00	3.00	2.25	83.50	83.50	2.54	2.07
40.	Elappapoochemban	25.00	32.50	7.00	3.50	83.50	82.50	2.46	2.48
41	Kattamodan	29.50	49.50	9.00	3.50	75.50	86.50	2.44	2.72
42	Kutticheradi	39.00	56.00	6.00	3.00	87.50	89.50	3.13	2.23
43.	Kuruwa	30.50	52.50	5.35	2.00	84.50	86.50	3.12	2.32
44.	Kavunginpoothala	41.00	53.50	8.75	3.75	73.00	81.50	2.73	2.82

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
45.	Navara	28.50	50.50	10.00	2.50	82.50	83.50	2.20	2.47
46.	Pavizhachembavu	23.00	59.00	6.75	5.00	92.50	91.00	2.37	2.39
47.	Thrissur local - 1	26.50	36.50	11.00	5.00	93.00	93.50	3.38	2.34
48.	Ponnaryan	23.50	36.50	3.50	2.75	73.00	85.50	2.32	2.35
49.	Sinduram	36.00	55.00	5.00	3.00	78.50	92.50	2.38	2.41
50.	Thekken	34.00	45.50	6.75	5.00	85.50	86.50	2.22	2.48
51.	Thekkencheera	23.50	35.50	10.75	5.00	86.50	86.50	1.98	2.07
52.	Teena	31.00	57.50	5.50	2.50	82.75	83.00	2.56	2.04
53.	Vadakken Chitteni	29.50	53.50	5.50	4.00	79.00	79.50	2.24	1.96
54.	Vellari	26.50	55.00	5.00	4.25	81.00	81.50	2.08	2.30
55.	Veluthavattan	33.00	46.50	4.00	3.50	83.50	84.50	2.58	2.71
56.	Veluthari Thavalakannan	26.50	45.50	10.50	4.00	86.50	85.50	2.48	2.84
57.	Thrissur local-2	26.50	38.00	10.00	5.50	82.75	83.50	2.36	2.54
58.	Aranmula local	29.50	60.00	5.00	4.75	78.50	82.50	2.75	1.74
	Mean	**29.50**	**48.14**	**7.49**	**4.00**	**82.82**	**85.04**	**2.58**	**2.40**
Other improved/market varieties									
59.	CO-25	23.00	45.50	10.00	3.00	84.00	81.50	2.02	2.17
60.	Mashuri	22.50	34.50	3.00	1.50	87.50	85.50	1.98	2.01
	Mean	**22.75**	**40.00**	**6.50**	**2.25**	**85.75**	**83.50**	**2.00**	**2.09**
	Gross Mean	29.79	48.89	**6.98**	3.68	**84.78**	**86.57**	**2.40**	**2.39**
	CD values								
	Varieties	1.847		0.635		1.184		0.032	
	Processing	0.337		0.116		0.216		0.006	
	Variety x processing	2.613		0.898		1.675		0.044	

A significant difference in gruel loss was observed in different rice varieties. The gruel loss was higher in traditional varieties (7.49 per cent) than in hybrid derivatives (6.55 per cent) and other improved varieties (6.50 per cent) in raw samples. The percentage of gruel loss was in the range of 3.00 to 11.50 per cent, 2.5 to 11.25 per cent and 3.00 to 10.00 per cent in the case of traditional, hybrid and other improved varieties respectively. The lowest gruel loss was found in *Triveni* (2.50 per cent), *Chuvannari Thavalakannan* (3.00 per cent) and *Mashuri* (3.00 per cent) in the case of hybrid, traditional and other improved varieties while the highest gruel loss was observed for the variety *Remya* (11.25 per cent), *Chettivirippu* (11.50 per cent) and *CO-25* (10.00 per cent) in the above three respective groups.

Higher the gruel loss, greater will be the nutrient loss. Hence decreased gruel loss is advantageous from the nutritional point of view. The loss of solids in the gruel of raw, soft parboiled and hard parboiled rice was reported as 4.5, 3.5 and 2 per cent respectively by Bhattacharya and Subha Rao (1966).

In the present study, almost all the varieties showed a minimum loss in gruel when parboiled because the starch is already gelatinized in parboiled rice. Parboiled rice of traditional varieties showed a higher gruel loss (4.00 per cent) when compared to hybrid derivatives (3.35 per cent). This finding is in agreement with earlier studies of Rajalakshmi (1984) and Sreedevi (1989).

The highest gruel loss after parboiling was observed for the traditional variety *Chettivirippu* (7.00 per cent) followed by the two hybrid derivatives *Remya* (5.5 per cent) and *Sagara* (5.5 per cent).

In traditional varieties, the gruel loss was in the range of 2.00 *(Kuruwa)* to 7.00 *(Chettivirippu)* per cent while in hybrid derivatives it ranged between 2.00 *(Triveni, Kanakom, Jyothi, Bhagya)* and 5.50 *(Remya* and *Sagara)* per cent. In other improved varieties it ranged between 1.50 in *Mashuri* and 3.00 per cent in *CO-25*.

A significant positive correlation was also observed for gruel loss with moisture ($r = 0.162^{**}$) and gelatinization temperature ($r = 0.153^{*}$) (Appendix 6)

The data also revealed that the interaction between varieties and processing was also significant.

Gruel loss is a negative indicator since Keralites prefer grains which has less leaching loss during cooking: This fact becomes all the more important in this context since the method of cooking rice popularly adopted in kerala is "cooking in excess water and straining".

4.2.3 Gelatinization temperature (Table 4 (a) and Appendix 5)

The gelatinization temperature seems to be a major determinant in deciding a particular cultivar for its suitability for processing, this property itself is not strictly reported to be variety specific. 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. In the case of raw samples hybrid derivatives were found to have higher gelatinization temperature (86.54°C) when compared to traditional (82.82°C) and other improved varieties (85.75°C).

The lowest gelatinization temperature was noticed in hybrid derivative *Jayathi* (74.5°C) in the range of 74.59 to 95.50°C followed by traditional variety *Kavunginpoothala* (73C°) and *Ponnaryan* (73C°) in the range of 73.00 to 93°C. In other improved varieties it ranged between 84.00(CO-25) and 87.50°C(Mashuri). The highest gelatinization temperature was observed for the hybrid variety *Bhadra* (95.50°C) and traditional variety *Thrissur local-1* (93°C).

The gelatinization temperature is influenced by processing methods. A significantly higher gelatinization temperature was seen in parboiled rice samples when compared to raw samples. Earlier studies indicated that gelatinization temperature is related to the texture of cooked rice (IRRI, 1977) and processing of rice varieties were found to influence positively the gelatinization temperature when compared to raw rice. Similar findings were also reported by Ali and Bhattacharya (1980) and Sreedevi (1989).

A comparison of different parboiled samples revealed that hybrid derivatives were found to have higher gelatinization temperature (88.2°C) and in the range of 75.50 to 94.50°C followed by traditional variety (85.04°C) falling in the range of 78.50 to 93.50°C. In other improved varieties it ranged from 81.50 to 85.50°C. The highest gelatinization temperature was observed in *Remya, Thrissur local-1* and *Mashuri* in the case of hybrid, traditional and other improved varieties respectively while the lowest temperature was noticed in *Nila, Aruvakkari* and *CO-25* in the above three groups quoted earlier.

In the present study gelatinization temperature is found to be positively associated with the cooking time (r = 0.182**) and thousand grain weight (r = 0.137*) and negatively with elongation ratio (r = -0.159*) and elongation index (r = -0.169*) (Appendix 6). This finding is on par with the studies of Swaminathan (1971) and Chatterjee and Maiti (1981).

Gelatinization temperature was observed to be negatively associated with the total amylose content. Resurreccion *et al.* (1977) have also reported that a high ambient temperature during grain development in rice results in a higher gelatinization temperature and vice-versa.

The data also revealed that the interaction between varieties and processing was also significant.

4.2.4 Viscosity (Table 4 (a) and Appendix 5)

Viscosity is a measure of the resistance of a fluid to shear forces and hence to flow (Anon., 1991).

A significant variation in the viscosity was observed among different varieties of rice as given in Table 4 (a). Traditional varieties were found to have higher viscosity (2.58 NSm^{-2}) when compared to hybrid derivatives (2.39 NSm^{-2}) and other improved varieties (2.00 NSm^{-2}). Viscosity of traditional varieties was found to be in the range of 1.97 NSm^{-2} *(Chenkayama)* to 3.38 NSm^{-2} *(Thrissur local - 1)* while in hybrid derivatives it was in the range of 1.90 NSm^{-2} *(Bhagya)* to 3.30 NSm^{-2} *(Karthika)*. In other improved varieties the range observed was 1.98 NSm^{-2} *(Mashuri)* to 2.02 NSm^{-2} *(CO-25)*.

Processing methods were found to influence significantly the viscosity of different rice varieties. In general, parboiling was found to increase the viscosity of rice samples. This might be due to decrease in fluidity due to the dissolution of cooked starch in cooking water. But in some varieties the viscosity was found to decrease as a result of parboiling. Hybrid derivatives were found to have higher viscosity (2.56 NSm^{-2}) falling in the range of 1.90 *(Asha)* to 3.21 NSm^{-2} *(Swarnamodan)* followed by traditional varieties with a viscosity in the range of 1.74 *(Aranmula local)* to 3.05 NSm^{-2} *(Aryankali)*. In other improved varieties the range observed was 2.01 *(Mashuri)* to 2.17 NSm^{-2} *(CO-25)*.

In the present study it was found that increase in protein content of the kernel resulted in the suppression of viscosity. This fact was observed in varieties like *Bhagya*, *Aruna* and *Nila*, the varieties that have a higher protein content than the other varieties under focus. Similar findings were also reported by IRRI (1963). A significant negative correlation was observed between viscosity and elongation index ($r = -0.135^*$) (Appendix 6). The data also revealed that the interaction between varieties and processing was also significant.

4.2.5 Water uptake (Table 4(b) and Appendix 5)

Water uptake is the weight of moisture absorbed by the grain during cooking.

The water uptake by the rice varieties were found to vary significantly.

Hybrid derivatives were found to have higher water uptake (3.55 g/g) when compared to traditional varieties (3.38 g/g). A comparison among raw samples revealed that the water up take ranged between 2.35 *(Hraswa)* and 5.25 g/g *(CSRC collection* and *Red Triveni)* in hybrid derivatives while it ranged between 2.45 *(Veluthari Thavalakannan)* and 5.25 g/g *(Aranmula local)* in traditional varieties and in other improved varieties the water uptake was 3.25 g/g *(Mashuri* and *CO-25)*.

A higher water uptake is an indicator of better cooking quality of rice. The uptake of water is found to be related to the surface area (Govindaswamy, 1985). In the present study water uptake was found to be high in small and slender varieties, because they have high surface area per gram. Similar findings were also reported by Bhattacharya and Sowbhagya (1971).

The water uptake of different rice varieties were found to vary significantly as a result of parboiling. The water uptake decreased significantly after parboiling when compared to raw rice. Parboiling changes the absorptive capacity of rice and radically alters the hydration characteristics. Thus parboiled rice samples were found to absorb a lesser amount of water during cooking. Similar results were reported by Damir (1985).

A comparison among parboiled samples revealed that hybrid derivatives were found to have higher water uptake (3.19 g/g) in which it ranged between 2.25 and 4.40 g/g followed by traditional varieties (2.99 g/g) where it ranged between 2.10 and 4.30 g/g. In other improved varieties it ranged between 3.15 and 3.20 g/g.

Water uptake was highest in *CSRC collection* (4.40 g/g), *Jyothi* (4.40 g/g), *Aranmula local* (4.30 g/g) and *CO-25* (3.20 g/g) in the case of hybrid, traditional and other improved varieties respectively while the lowest water uptake was noticed in *Hraswa* (2.25 g/g), *Aryan* (2.10 g/g) and *Mashuri* (3.15 g/g) in the above three respective groups.

Size of the grain and cooking temperature are reported to influence the hydration characteristics of the rice grains (Geervani and George, 1971). In the present study gelatinization temperature was found to influence the cooking behaviour. The degree of gelatinization is directly proportional to the hydration ability of the resultant rice. This observation is in accordance with the findings of Chatterjee and Maiti (1981).

Govinda Swamy and Ghosh (1970) had reported that water uptake was negatively correlated with the protein content.

A significant positive correlation was observed by the three characteristics viz., volume expansion (r = 0.971**), moisture (r = 0.276**), and gelatinization temperature with water uptake (r = 0.139*) (Appendix 6).

In this context the interaction between variety and processing was also found to be significant.

Table 4 (b) Selected cooking characteristics of rice varieties

Sl. No	Variety	Water uptake (g/g) Raw	Water uptake (g/g) Parboiled	Volume expansion (ratio) Raw	Volume expansion (ratio) Parboiled	Elongation ratio Raw	Elongation ratio Parboiled	Elongation index Raw	Elongation index Parboiled
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Hybrid derivatives									
1.	Annapoorna	3.10	3.05	4.10	4.05	1.40	1.69	1.44	1.69
2.	Aruna	4.10	3.90	5.10	4.90	1.67	1.75	1.69	1.75
3.	Asha	3.70	3.45	4.20	4.90	1.56	1.54	1.56	1.54
4.	Bhadra	3.40	3.25	3.90	4.25	1.54	1.56	1.54	1.56
5.	Bharathy	2.85	2.70	3.85	3.70	1.34	1.55	1.34	1.55
6.	Bhagya	3.10	3.05	4.10	3.25	1.54	1.53	1.54	1.53
7.	CSRC collection	5.25	4.40	6.25	5.35	1.41	1.44	1.41	1.45
8.	Dhanya	3.50	3.40	4.50	4.40	1.63	1.63	1.63	1.63
9.	Hraswa	2.35	2.25	3.35	3.05	1.41	1.42	1.41	1.40
10.	Jaya	4.30	3.50	5.30	4.50	1.58	1.54	1.54	1.54
11.	Jayathi	2.85	2.75	3.85	3.75	1.75	1.71	1.75	1.81
12.	Jyothi	4.45	4.40	5.45	5.40	1.50	1.63	1.50	1.63
13.	Kanakom	3.60	3.10	4.60	4.10	1.58	1.58	1.61	1.58
14.	Karthika	3.70	2.70	4.70	3.70	1.40	1.47	1.40	1.47
15.	Lakshmi	2.70	2.40	3.70	2.40	1.47	1.47	1.47	1.47
16.	Makom	3.60	3.45	4.60	4.45	1.42	1.45	1.42	1.45
17.	Neeraja	3.10	2.55	4.10	3.55	1.56	1.59	1.56	1.59
18.	Nila	2.70	2.30	3.70	3.30	1.81	1.78	1.85	1.71
19.	Onam	4.65	4.10	5.65	5.10	1.18	1.20	1.17	1.20
20.	Pavizham	3.70	3.55	4.70	4.55	1.88	1.81	1.88	1.78
21.	Red Triveni	5.25	4.35	6.25	5.40	1.42	1.47	1.40	1.47
22.	Remya	3.80	3.75	4.80	4.75	1.53	1.53	1.53	1.53

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
23.	Reshmi	3.10	3.05	4.10	4.05	1.70	1.70	1.70	1.67
24.	Sabari	4.45	3.65	5.45	4.65	1.40	1.39	1.59	1.59
25.	Sagara	2.90	2.80	3.90	3.80	1.64	1.64	1.67	1.64
26.	Swarnaprabha	3.75	2.80	4.75	3.80	1.36	1.36	1.37	1.36
27.	Swarnamodan	3.75	2.45	4.75	3.45	1.49	1.49	1.49	1.49
28.	Triveni	3.45	3.30	4.45	4.30	1.45	1.50	1.47	1.50
29.	Vyttila -1	2.70	2.60	3.70	3.60	1.37	1.43	1.37	1.43
30.	Vyttila-3	2.70	2.55	3.50	3.55	1.46	1.56	1.46	1.56
	Mean	**3.55**	**3.19**	**4.52**	**4.13**	**1.52**	**1.55**	**1.53**	**1.58**
Traditional/local varieties									
31.	Aruvakkari	3.15	3.00	4.15	4.00	1.67	1.49	1.69	1.49
32.	Aryankali	3.15	2.90	4.15	4.00	1.43	1.43	1.43	1.43
33.	Aryan	2.70	2.10	3.70	3.35	1.60	1.60	1.60	1.60
34.	Chenkayama	3.70	2.65	4.70	3.65	1.65	1.67	1.65	1.67
35.	Cheriya Aryan	3.05	2.90	4.05	3.90	1.54	1.54	1.56	1.54
36.	Chettivirippu	4.65	4.25	5.65	5.25	1.53	1.54	1.52	1.59
37.	Chitteni	3.50	3.40	4.50	4.40	1.63	1.63	1.68	1.63
38.	Chuvannamodan	2.70	2.65	3.70	3.65	1.36	1.41	1.36	1.35
39.	Chuvannari - Thavalakannan	3.70	3.35	4.70	4.35	1.55	1.55	1.57	1.55
40.	Elappapoochemban	3.20	2.70	4.20	3.70	1.62	1.60	1.62	1.60
41.	Kattamodan	2.60	2.50	3.60	3.50	1.38	1.38	1.37	1.38
42.	Kutticheradi	3.10	2.45	4.10	3.45	1.61	1.61	1.61	1.61
43.	Kuruwa	4.35	3.40	5.35	4.65	1.47	1.47	1.45	1.47
44.	Kavunginpoothala	3.90	3.80	4.90	4.80	1.37	1.35	1.37	1.41
45.	Navara	3.45	2.95	4.45	3.95	1.74	1.67	1.74	1.77

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
46.	Pavizhachembavu	3.50	3.20	4.50	4.20	1.59	1.59	1.59	1.59
47.	Thrissur local -1	3.45	3.15	4.45	4.15	1.68	1.70	1.68	1.70
48.	Ponnaryan	3.30	3.15	4.30	4.15	1.65	1.65	1.65	1.65
49.	Sinduram	3.65	2.70	4.65	3.70	1.62	1.66	1.65	1.66
50.	Thekken	3.35	3.20	4.35	4.20	1.70	1.69	1.69	1.69
51.	Thekkencheera	2.50	2.30	3.50	3.30	1.50	1.50	1.52	1.50
52.	Teena	2.90	2.80	3.90	3.80	1.64	1.53	1.64	1.53
53.	Vadakken Chitteni	3.10	2.50	4.10	3.50	1.60	1.61	1.62	1.61
54.	Vellari	3.70	2.70	4.60	3.70	1.55	1.58	1.55	1.58
55.	Veluthavattan	3.20	3.10	4.20	4.10	1.49	1.52	1.49	1.52
56.	Veluthari Thavalakannan	2.45	2.35	3.45	3.10	1.72	1.77	1.72	1.72
57.	Thrissur local-2	3.25	3.15	4.25	4.15	1.70	1.72	1.72	1.67
58.	Aranmula local	5.25	4.30	6.25	5.30	1.59	1.59	1.59	1.65
	Mean	**3.38**	**2.99**	**4.37**	**3.99**	**1.57**	**1.57**	**1.55**	**1.58**
Other improved/market varieties									
59.	CO-25	3.25	3.20	4.25	4.25	1.93	1.95	1.93	1.95
60.	Mashuri	3.25	3.15	4.30	4.15	1.84	1.83	1.89	1.83
	Mean	**3.25**	**3.18**	**4.28**	**4.20**	**1.89**	**1.89**	**1.91**	**1.89**
	Gross Mean	**3.46**	**3.09**	**4.44**	**4.07**	**1.56**	**1.57**	**1.56**	**1.57**
	CD Values								
	Varieties	0.276		0.275		0.212		0.213	
	Processing	0.050		0.050					
	Variety x processing	0.390		0.389					

4.2.6 Volume expansion (Table 4(b) and Appendix 5)

Volume expansion or kernel expansion is determined from the ratio between the cooked volume of rice to that of the uncooked rice.

A higher value for this parameter generally indicates a higher cooked volume of rice.

A comparison of the varieties revealed that volume expansion was found to vary significantly among the different rice varieties. The volume expansion was found to be higher in hybrid derivatives (4.52) than in traditional (4.37) and other improved varieties (4.28).

In the three groups of rice varieties, viz., hybrid, traditional and other improved varieties, the highest volume expansion was found in *Red Triveni* (6.25) and *CSRC collection* (6.25), *Aranmula local* (6.25) and *Mashuri* (4.30) while the expansion was lowest in *Hraswa* (3.35), *Veluthari Thavalakannan* (3.45) and *CO-25* (4.25) in the above three respective groups.

Higher volume expansion after cooking is a desirable trait preferred by consumers. In the present study volume expansion depended on water uptake. Increased expansion was found in those varieties which had a higher water uptake.

The volume expansion was found to decrease significantly in the case of parboiled rice when compared to raw rice. This may probably be due to loosened husk and other factors related to changes brought about during the parboiling operations. In parboiled rice, higher expansion was found among hybrid derivatives (4.13) than in traditional varieties (3.99). This observation is in concordance with the findings of Mahadevappa and Desikachar (1968) and Sreedevi (1989) who had stated that volume expansion was found to be more in hybrid derivatives. The highest volume expansion was observed in *Red Triveni* (5.40) and *Jyothi* (5.40), *Aranmula local* (5.30) and *CO -25* (4.25) with respect to hybrid, traditional and other improved varieties respectively while the lowest expansion was found in *Hraswa* (3.05), *Veluthari thavalakannan* (3.10) and *Mashuri* (4.15) in the above three groups mentioned earlier.

The interaction between variety and processing was also found to be significant.

4.2.7 Elongation ratio (Table 4(b) and Appendix 5)

Elongation ratio is the ratio between the length of cooked grain and that of the raw grain.

A significant varietal difference was observed in the elongation ratio of different rice varieties. Elongation ratio of other improved varieties were found to be higher (1.89) when compared to traditional varieties (1.57) and hybrid derivatives (1.52). The ratio ranged between 1.18 *(Onam)* and 1.88 *(Pavizham)* in the case of hybrid derivatives while in traditional/local varieties the ratio ranged between 1.36 *(Chuvannamodan)* and 1.74 *(Navara)*. In other improved varieties the ratio is 1.84 *(Mashuri)* and 1.93 *(CO-25) respectively.*

There were visible differences in the elongation ratio of different rice varieties after parboiling. A slight increase in the elongation ratio was observed after parboiling in the case of hybrid derivatives (1.55). The elongation ratio ranged between 1.20 *(Onam)* and 1.81 *(Pavizham)*, 1.35 *(Kavunginpoothala)* and 1.77 *(Veluthari Thavalakannan)* and 1.83 *(Mashuri)* and 1.95 *(CO -25)* in the case of hybrid, traditional and other improved varieties. An increase in length during cooking is a desired trait in determining the quality of rice. Similar observations were reported from IRRI (1986) in the case of *Basmati 370* variety.

4.2.8 Elongation index (Table 4(b) and Appendix 5)

Elongation index is the ratio between the length and width of cooked grain and that of the uncooked grain. The elongation index will give an idea of the percentage increase in grain dimension after cooking which is a desirable trait while estimating the acceptability of the varieties.

As revealed in table 4(b) the elongation index of rice varieties varied significantly. Other improved varieties were found to have higher elongation index (1.91) when compared to traditional varieties (1.55) and hybrid derivatives (1.53). The elongation index of hybrid derivatives ranged between 1.17 *(Onam)* and 1.88 *(Pavizham)* while in traditional varieties it ranged between 1.36 *(Chuvannamodan)* and 1.74 *(Navara)*. In other improved varieties the index was 1.89 and 1.93 for *Mashuri* and *CO-25* respectively.

A significant difference was noticed in the elongation index of different rice varieties after processing. A slight increase in the elongation index was noticed after parboiling. This might be due to short and plump appearance of the grains. Similar trends in the results were observed by Mahadevappa and Desikachar (1968 a) in their studies on parboiling of rice.

The elongation index ranged between 1.20 *(Onam)* to 1.81 *(Jayathi)*, 1.35 *(Chuvannamodan)* to 1.77 *(Navara)* in the case of hybrid derivatives and traditional varieties respectively. In other improved varieties the index was 1.83 for *Mashuri* and 1.95 for *CO -25*.

A good quality rice grain is expected to get lower values for optimum cooking time, gruel loss, gelatinization temperature and viscosity and higher values for water uptake, volume expansion, elongation ratio and elongation index. Hybrid derivatives studied were found to give satisfying grades for the indicators like water uptake, volume expansion and gruel loss while traditional varieties were found to give higher values for gruel loss and viscosity which are negative indicators. Among the three groups, other improved varieties had ideal values for optimum cooking time, viscosity, gruel loss, elongation ratio and elongation index.

Parboiling was found to increase the optimum cooking time and decrease the gruel loss in all the rice varieties studied. A slight increase in the gelatinization temperature, elongation ratio and elongation index were noticed in hybrid and traditional varieties and a decrease in water uptake and volume expansion were observed as a result of parboiling.

Among the hybrid derivatives, varieties such as *Bharathy, Jaya, Triveni CSRC* collection, *Red Triveni, Sabari,* and *Jyothi, Hraswa, Remya, Vyttila-1, Vyttila-3* were found to satisfy all the indicators selected under cooking characteristics and among other improved varieties, *Aranmula local, Chettivirippu, Kuruwa, Chuvannari Thavalakannan, Ponnaryan, Veluthavattan, Vadakken Chitteni* and *Aryan, Kattamodan, Chitteni, Kutticheradi, Chenkayama* could also be classified to have similar quality attributes.

Among these, varieties such as *Bharathy, Kuruwa, Aryan* and *Chuvannari Thavalakannan* were also found to satisfy the norms fixed for physical characteristics like thousand grain weight, head rice yield, L/B ratio and moisture content.

4.2.9 Salient findings

A good quality grain gets lower values for optimum cooking time, gruel loss, gelatinization temperature and viscosity and higher values for water uptake, volume expansion, elongation ratio and elongation index. Compared to traditional varieties, rice grains studied under hybrid derivatives were found to give better performance for indicators such as gruel loss, viscosity, water uptake and volume expansion.

Among these, optimum cooking time, gruel loss, water uptake and volume expansion were found to influence the hydration characteristics and cooking behaviour of the rice grains.

The hybrid derivatives of larger grain size were found to have higher values for optimum cooking time, greater water uptake, volume expansion and less gruel loss when compared to smaller grains of traditional varieties. Further all these indicators became better as result of parboiling. In traditional varieties, the results of the above mentioned indicators observed a different parttern. Hence among the various indicators studied under cooking characteristics, the four indicators (water uptake, volume expansion, optimum cooking time and gruel loss) now identified can be suggested as suitable indicators for determining the quality of the grains (bold, extra bold, slender or short).

4.3 ORGANOLEPTIC CHARACTERISTICS AND SUITABILITY FOR DIFFERENT RICE PREPARATIONS (Table 5, 6, 7, 8, 9, 10, 11 and 12 Appendix 8 and Figure 1).

Quality has been defined as degree of excellence and is the composite of characteristics determining acceptability. The eating quality of rice is usually judged by the sensory evaluation, which seems unscientific and variable according to personal preference (Lii and Chang, 1986). Sensory evaluation of any food is assumed significant as this provides information for both product improvement and product development. According to Kramer and Twigg (1970) food quality detectable by our senses can be broken into three main categories-appearance factors, textural factors and flavour factors. Studies had also indicated that colour and taste of any product play a vital role in deciding its popularity and acceptability.

Different methods of cooking increases the organoleptic qualities of food especially flavour or aroma. It stimulates the secretion of the digestive juices and aids in effective digestion and assimilation of foods. Preservation of the maximum nutritive value as well as organoleptic quality can be ensured only by using correct methods of cooking, suited to particular foods. Wet cooking breaks up the starch cells in foods, making it softer and more accessible to starch-splitting enzymes. Different cooking methods bring about physical and chemical changes in the food whereby colour, texture and appearance may be improved. This increases palatability, acceptability and the digestibility of the food. The same food if cooked in different ways provides variety to the diet. Methods like steaming, baking and shallow frying needs less time to cook when compared to boiling in order to give variety to dishes prepared from a single food. Influence of different cooking methods on rice was ascertained by attempting seven different preparations (Table 5).

Quality attributes selected in this study were colour, appearance, flavour, texture and taste and the various preparations were made using standard recipes.

All the preparations were attempted using raw rice except in cooked parboiled rice and in steamed preparation made from fermented batter *(Iddli)*.

The attributes of appearance, tenderness and flavour of cooked rice are the final criteria of cooking quality and determine the palatability or eating characteristics of cooked rice (Bandyopadhyay and Roy, 1992).

Table 5 Different cooking methods selected for the study

Sl. No.	Precooking treatments	Cooking methods	Name of the preparation
1.	Raw milled rice (without any precooking treatment)	Boiling	Cooked rice
2.	Parboiling	Boiling	Cooked rice
3.	Fermenting	a) Steaming	Iddli
		b) Shallow frying	Dosa
4.	Powdering and roasting	a) Steaming	Puttu
		b) Boiling	Kozhukkatta
		c) Baking	Appam

4.3.1 Boiling (cooked rice-raw) Table 6

The mean score obtained for the quality attribute, appearance differed significantly among rice varieties. Other improved varieties were found to have higher mean scores (4.05) when compared to hybrid (3.45) and traditional varieties (3.34). The highest mean score (4.50) was observed in variety No 33 *(Aryan)* while the lowest in variety No.22 (1.80) *(Remya)*. Eight hybrid derivatives, eight traditional varieties and two other improved varieties were found to be on par with *Aryan. Similarly one hybrid derivative and three traditional varieties were found to be on par with Remya.*

A significant difference among the rice varieties were observed in the quality attribute colour. Other improved varieties were found to have higher mean scores (3.85) when compared to hybrid derivatives (3.41) and traditional varieties (3.43). The highest score (4.30) was noticed in variety No.11 *(Jayathi)* while the lowest (1.80) for *Remya*. Twelve hybrid derivatives, fourteen traditional and two other improved varieties were found to be on par with *Jayathi.* Similarly one hybrid derivative and two traditional varieties were also found to be on par with *Remya.*

There was a significant difference among the different rice varieties in the quality attribute flavour. Other improved varieties were found to have higher mean score (3.50) when compared to traditional varieties (3.18) and hybrid derivatives (3.15). The highest mean score (4.10) was noticed in variety No.30 *(Vyttila - 3)* while the lowest (1.40) in variety No.32 *(Aryankali)*. Twelve hybrid derivatives, thirteen traditional and two other improved varieties were found to be on par with *Vytilla - 3*. No other variety was found to have similar values like *Aryankali.*

A significant difference was observed in the quality attribute texture. Both the hybrid and traditional varieties were found to have the same mean score (3.23). The highest mean score (4.20) was noticed in variety No.29 *(Vyttila-1)* while the lowest 1.90 in variety *Remya*. Seven hybrid derivatives and nine traditional varieties were found to be on par with *Vyttila-1*. One hybrid derivative and three traditional varieties were also found to be on par with *Remya*

Table 6 Quality attributes of raw rice varieties due to boiling

Sl.No.	Variety	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
		Quality attributes (mean scores)					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hybrid derivatives							
1.	Annapoorna	3.80	3.50	3.40	3.20	3.50	3.42
2.	Aruna	3.90	3.30	2.60	3.10	3.00	3.18
3.	Asha	3.30	3.00	2.50	3.00	3.50	3.06
4.	Bhadra	2.80	3.20	2.70	2.50	2.80	2.80
5.	Bharathy	3.60	3.60	3.60	3.50	3.40	3.54
6.	Bhagya	3.40	3.50	2.60	3.10	3.50	3.22
7.	CSRC collection	3.00	2.20	2.90	2.70	3.10	2.78
8.	Dhanya	2.90	3.30	3.30	3.00	3.10	3.12
9.	Hraswa	3.40	3.20	3.10	3.20	3.90	3.36
10.	Jaya	3.60	2.90	2.70	3.20	3.50	3.18
11.	Jayathi	4.00	4.30	3.70	3.70	3.90	3.92
12.	Jyothi	4.10	3.80	3.40	4.00	3.60	3.78
13.	Kanakom	4.00	4.00	3.60	3.20	3.40	3.64
14.	Karthika	3.50	3.40	2.60	3.90	2.70	3.22
15.	Lakshmi	4.10	3.70	2.90	3.20	3.20	3.42
16.	Makom	3.00	3.10	2.80	2.90	2.90	2.94
17.	Neeraja	4.00	4.00	3.60	3.40	3.70	3.74
18.	Nila	2.50	2.60	3.50	3.00	3.00	2.92
19.	Onam	3.50	3.20	2.50	3.00	2.70	2.98
20.	Pavizham	3.40	3.00	2.80	2.80	3.20	3.04
21.	Red Triveni	3.60	3.10	3.10	3.10	3.30	3.24
22.	Remya	1.80	1.80	2.90	1.90	2.00	2.08

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
23.	Reshmi	3.40	3.80	3.40	3.60	3.50	3.54
24.	Sabari	3.30	3.70	3.00	3.30	3.40	3.34
25.	Sagara	3.50	3.70	3.40	3.40	3.40	3.48
26.	Swarnaprabha	4.20	3.90	3.40	3.70	3.50	3.74
27.	Swarnamodan	3.70	4.00	3.50	3.10	3.50	3.56
28.	Triveni	3.00	3.10	3.00	2.80	3.40	3.06
29.	Vyttila-1	3.90	4.10	4.00	4.20	4.00	4.04
30.	Vyttila-3	3.70	4.20	4.10	4.10	3.90	4.00
	Mean	**3.45**	**3.41**	**3.15**	**3.23**	**3.32**	**3.31**
Traditional/local varieties							
31.	Aruvakkari	3.70	3.60	3.40	3.20	3.60	3.50
32.	Aryankali	2.10	2.00	1.40	2.60	2.00	2.02
33.	Aryan	4.50	4.10	3.40	3.50	3.70	3.84
34.	Chenkayama	3.30	4.00	3.50	3.50	3.70	3.60
35.	Cheriya Aryan	2.80	3.30	2.70	2.80	3.00	2.92
36.	Chettivirippu	3.30	3.30	2.20	3.60	3.40	3.16
37.	Chitteni	3.30	2.90	3.70	3.30	3.80	3.40
38.	Chuvannamodan	3.90	3.80	3.50	3.50	4.20	3.78
39.	Chuvannari - Thavalakannan	2.10	2.20	2.60	2.40	2.60	2.38
40.	Elappapoochemban	3.90	3.70	3.40	3.20	3.50	3.54
41.	Kattamodan	4.30	4.10	3.60	4.00	3.70	3.94
42.	Kutticheradi	2.90	2.70	3.20	2.80	2.90	2.90
43.	Kuruwa	3.20	3.40	3.40	3.30	3.50	3.36
44.	Kavunginpoothala	3.00	3.00	3.30	3.30	3.30	3.18
45.	Navara	3.10	3.40	3.40	2.80	3.10	3.16

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
46.	Pavizhachembavu	3.10	3.00	3.00	2.80	2.90	2.96
47.	Thrissur local-1	3.80	3.90	3.60	3.70	3.80	3.76
48.	Ponnaryan	4.00	3.60	3.20	2.70	3.00	3.30
49.	Sinduram	3.00	3.30	3.00	3.00	3.40	3.14
50.	Thekken	3.00	4.00	3.80	3.70	3.50	3.60
51.	Thekkencheera	3.30	3.20	2.80	2.90	2.90	3.02
52.	Teena	2.40	2.70	3.10	2.60	2.70	2.70
53.	Vadakken Chitteni	3.90	3.90	3.30	3.50	3.80	3.68
54.	Vellari	3.90	4.20	3.50	3.90	4.00	3.90
55.	Veluthavattan	4.10	3.90	3.60	4.20	4.00	3.96
56.	Veluthari Thavalakannan	3.30	3.50	2.90	3.10	3.10	3.18
57.	Thrissur local-2	2.90	3.60	3.30	3.10	3.30	3.24
58.	Aranmula local	3.40	3.60	3.20	3.30	3.60	3.42
	Mean	**3.34**	**3.43**	**3.18**	**3.23**	**3.36**	**3.31**
Other improved/market varieties							
59.	CO-25	4.10	4.00	3.60	3.40	3.90	3.80
60.	Mashuri	4.00	3.70	3.40	3.00	3.60	3.54
	Mean	**4.05**	**3.85**	**3.50**	**3.20**	**3.75**	**3.67**
	Gross Mean	3.42	3.43	3.18	3.23	3.35	3.32
	F	4.464**	4.020**	3.111 **	3.030**	2.940 **	4.725**
	SE	0.268	0.279	0.263	0.264	0.265	0.200
	CD	0.743	0.773	0.731	0.732	0.734	0.555

**Significant at 1% level

Significant ~~cultural~~ differences in taste were noticed among different rice varieties. Other improved varieties were found to have higher mean scores (3.75) when compared to hybrid (3.32) and traditional varieties (3.36). The highest score was (4.20) noticed in variety No.38 *(Chuvannamodan)* while the lowest (2.00) in variety *Remya*. Thirteen hybrid, thirteen traditional and two other imporved varieties were found to be on par with *Chuvannamodan*. Two hybrid derivatives and three traditional varieties were also found to be on par with *Remya*.

The overall acceptability of the preparation also differed significantly among rice varieties. Both hybrid and traditional varieties were found to have same mean score (3.31) where as the mean score of other improved varieties was found to be 3.67. The highest score (4.04) was noticed for the variety *(Vyttila - 1)* while the lowest score was obtained by *Aryankali*. Nine hybrid derivatives, eleven traditional varieties and two other improved varieties were found to be on par with Vyttila-1. Hybrid derivatives such as *Bharathy, Jayathi, Jyothi, Kanakom, Neeraja, Reshmi, Swarnaprabha, Swarnamodan, Vyttila-1, Vyttila-3* and traditional varieties such as *Aruvakkari, Aryan, Chenkayama, Chuvannamodan, Elappapoochemban, Kattamodan, Thrissur local-1, Thekken, Vadakken Chitteni, Vellari, Veluthavattan* and other improved varieties *CO-25* and *Mashuri* were found to be highly suitable for the preparation cooked rice and varieties such as *Aryankali, Remya* and *Chuvannari Thavalakannan* were found unsuitable for this preparation.

4.3.2. Boiling (Cooked rice - parboiled) (Table 7)

The mean score obtained for the quality attribute appearance differed significantly among rice varieties. Hybrid derivatives were found to have higher mean scores (3.38) when compared to traditional varieties (3.23) and other improved varieties (3.30). The highest mean score (4.60) was observed in variety No.55 *(Veluthavattan)* while the lowest (2.20) in variety No. 45 *(Navara)*. Eleven hybrid derivatives and five traditional varieties were found to be on par with *Veluthavattan* where as eleven hybrid varieties and ten traditional varieties were found to have scores similar to that of *Navara*.

There was a significant difference among the different rice varieties in the quality attribute colour. Hybrid derivatives were found to have higher mean score (3.49) when compared to other improved varieties (3.15) and traditional varieties (3.25). The highest

Table 7 Quality attributes of parboiled rice varieties due to boiling

Sl.No.	Variety	Quality attributes (mean scores) Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hybrid derivatives							
1.	Annapoorna	2.90	3.50	3.50	3.50	3.90	3.46
2.	Aruna	4.20	3.90	3.90	3.60	3.60	3.84
3.	Asha	3.90	4.00	3.60	3.30	4.00	3.76
4.	Bhadra	3.80	4.00	3.40	3.60	4.10	3.78
5.	Bharathy	2.50	2.80	2.60	2.40	3.00	2.66
6.	Bhagya	2.90	2.90	3.40	3.30	3.20	3.14
7.	CSRC collection	2.80	2.80	1.60	2.90	2.10	2.44
8.	Dhanya	3.30	3.40	3.80	3.60	3.60	3.54
9.	Hraswa	3.80	3.60	3.50	3.20	3.40	3.50
10.	Jaya	2.80	2.80	2.80	3.60	2.80	2.96
11.	Jayathi	3.50	3.40	3.30	3.20	3.30	3.34
12.	Jyothi	2.90	3.40	3.00	3.00	2.90	3.04
13.	Kanakom	3.90	3.70	3.80	3.40	3.70	3.70
14.	Karthika	3.60	3.90	3.90	3.60	3.70	3.74
15.	Lakshmi	2.60	2.90	3.40	3.30	3.70	3.18
16.	Makom	3.10	3.30	3.60	3.20	3.50	3.34
17.	Neeraja	3.20	3.40	2.90	3.40	3.30	3.24
18.	Nila	2.60	3.50	3.70	3.30	3.60	3.34
19.	Onam	4.00	4.00	3.20	2.60	3.00	3.36
20.	Pavizham	4.40	4.30	4.10	4.00	4.50	4.26
21.	Red Triveni	3.50	3.30	3.20	2.80	3.10	3.18

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
22.	Remya	4.10	3.70	3.60	3.40	3.30	3.62
23.	Reshmi	2.80	3.40	3.70	3.20	3.90	3.40
24.	Sabari	3.20	3.00	2.80	3.50	2.60	3.02
25.	Sagara	2.50	3.20	3.10	3.50	3.50	3.16
26.	Swarnaprabha	2.80	3.20	3.00	3.30	3.00	3.06
27.	Swarnamodan	4.00	3.80	3.40	3.10	3.30	3.52
28.	Triveni	3.40	3.50	3.70	3.20	3.70	3.50
29.	Vyttila-1	4.20	4.20	4.10	3.90	3.90	4.06
30.	Vyttila-3	4.10	3.90	4.10	3.90	3.70	3.94
	Mean	**3.38**	**3.49**	**3.39**	**3.32**	**3.33**	**3.40**
Traditional/local varieties							
31.	Aruvakkari	2.60	2.90	3.50	3.20	3.20	3.08
32.	Aryankali	3.20	3.30	3.80	3.40	3.50	3.44
33.	Aryan	3.50	3.40	3.40	3.50	3.50	3.46
34.	Chenkayama	4.10	3.80	3.60	3.60	3.50	3.72
35.	Cheriya Aryan	4.00	3.80	3.70	3.40	3.50	3.68
36.	Chettivirippu	3.70	3.90	3.80	3.30	3.30	3.60
37.	Chitteni	2.70	2.60	3.60	3.10	3.30	3.06
38.	Chuvannamodan	4.40	4.00	3.40	3.60	3.60	3.80
39.	Chuvannari Thavalakannan	2.70	2.80	3.70	3.40	3.70	3.26
40.	Elappapoochemban	4.30	3.90	3.30	3.70	3.40	3.72
41.	Kattamodan	3.40	3.40	2.90	2.90	3.10	3.14
42.	Kutticheradi	2.90	3.00	3.10	2.80	3.10	2.98
43.	Kuruwa	2.40	2.60	2.20	2.40	1.70	2.26
44.	Kavunginpoothala	2.60	2.90	3.00	2.40	2.40	2.66
45.	Navara	2.20	2.10	3.20	2.70	2.80	2.60

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
46.	Pavizhachembavu	3.10	3.10	3.00	3.50	3.40	3.22
47.	Thrissur local-1	3.80	3.60	3.50	3.20	3.10	3.44
48.	Ponnaryan	3.10	3.30	3.80	3.30	3.50	3.40
49.	Sinduram	2.80	2.90	3.00	2.80	2.90	2.88
50.	Thekken	3.50	3.80	3.60	3.20	3.50	3.52
51.	Thekkencheera	3.00	3.50	3.70	3.20	3.40	3.36
52.	Teena	2.70	2.80	3.10	3.30	3.30	3.04
53.	Vadakken Chitteni	3.50	3.20	3.50	3.20	3.50	3.38
54.	Vellari	3.00	2.80	3.80	2.50	3.10	3.04
55.	Veluthavattan	4.60	4.70	4.00	3.10	3.90	4.06
56.	Veluthari Thavalakannan	3.40	3.70	3.90	3.60	3.50	3.62
57.	Thrissur local-2	2.10	2.00	2.90	2.80	2.70	2.50
58.	Aranmula local	3.20	3.30	3.10	2.50	2.90	3.00
	Mean	**3.23**	**3.25**	**3.40**	**3.13**	**3.23**	**3.25**
Other improved/market varieties							
59.	CO-25	3.40	3.30	3.20	3.40	3.70	3.40
60.	Mashuri	3.20	3.00	3.50	3.50	3.50	3.34
	Mean	**3.30**	**3.15**	**3.35**	**3.45**	**3.60**	**3.37**
	Gross Mean	**3.31**	**3.37**	**3.39**	**3.24**	**3.34**	**3.33**
	F	4.528**	3.012**	2.887**	1.577**	2.358 **	3.43**
	SE	0.287	0.298	0.274	0.298	0.305	0.183
	CD	0.797	0.828	0.761	0.827	0.847	0.608

**Significant at 1% level

mean score (4.70) was noticed again in *Veluthavattan* while the lowest (2.10) again in *Navara.* Eight hybrid derivatives and two traditional varieties were found to have similar scores of *Veluthavattan* where as five hybrid derivatives and nine traditional varieties were also found to have similar score of *Narava.* The high mean score for parboiled rice varieties may probably be due to the dissolving of colouring pigments in the hull.

Significant differences among the rice varieties were observed in the quality attribute flavour. Traditional varieties were found to have higher mean scores (3.40) when compared to other improved varieties (3.35) and hybrid derivatives (3.39). The highest mean score (4.10) was noticed in variety No 20 *(Pavizham)* while the lowest (1.60) in variety No.7 *(CSRC collection).* Eighteen hybrid derivatives, seventeen traditional varieties and one improved variety were found to have similar scores of *Pavizham* where as only one traditional variety was found to have similar score of *CSRC collection.* Parboiled rice has a characteristic aroma and taste which is accepted only by the traditional rice eating people. The flavour of the parboiled product is the result of hydrolysis and decomposition of certain constituents such as carbohydrates and proteins (Bandyopadhyay and Roy, 1992).

A significant difference was also observed among different varieties in the quality attribute texture. Other improved varieties were found to have higher mean scores (3.45) when compared to traditional varieties (3.13) and hybrid derivatives (3.32). The highest mean score (4.00) was noticed in *Pavizham* while the lowest (2.40) in variety *Bharathy.* Twenty three hybrid derivatives, seventeen traditional varieties and two other improved varieties were found to be on par with *Pavizham* where as eight hybrid derivatives and eighteen traditional varieties were also found to have lowest scores as far this preparation is concerned. According to Juliano and Villareal (1981) the harder texture of cooked rice product is mainly due to the higher molecular weight of their amylopectin. Low scores for parboiled cooked rice may also be due to rice bran.

Significant differences were also noticed among rice varieties for the quality attribute taste. Other improved varieties were found to have higher mean scores (3.60) when compared to traditional varieties (3.23) and hybrid derivatives (3.33). The highest mean score (4.50) was observed in *Pavizham* while the lowest (1.70) in variety No. 43 *(Kuruwa).* Eleven hybrid derivatives, two traditional varieties and one other improved variety were found to have similar scores of *Pavizham* where as only one hybrid derivative and one traditional variety were found to have similar scores of *Kuruwa*. Parboiled varieties were preferred most for their taste.

The overall acceptability of this preparation also differed significantly among rice varieties. Hybrid derivatives were found to have higher mean scores (3.40) when compared to traditional varieties (3.25) and other improved varieties (3.37). The highest score (4.26) was again noticed in *Pavizham* while the lowest (2.26) in *Kuruwa*. Seven hybrid derivatives and five traditional varieties were found to have similar scores of *Pavizham*.

Out of sixty varieties only ten varieties were found highly suitable for the preparation of cooked rice. All the varieties suitable to prepare cooked rice were not found to possess same qualities when parboiled. Hybrid derivatives such as *Aruna, Asha, Bhadra, Kanakom, Karthika, Vyttila-1, Vyttila-3 and Pavizham* and traditional varieties such as *Chenkayama, Cheriya Aryan, Chuvannamodan, Veluthavattan* and *Elappapoochemban* after parboiling were found to be highly suitable for this preparation while varieties such as *Bharathy, CSRC collection, Kuruwa, Kavunginpoothala, Navara* and *Thrissur local-2* were found to be highly unsuitable. Varieties such as *Kanakom, Chenkayama, Chuvannamodan, Vyttila-1, Vyttila-3, Veluthavattan* and *Elappapoochemban* were found to be suitable for preparing cooked rice either in raw or in parboiled form.

Among the individual quality attributes, traditional variety *Veluthavattan* scored the highest value for appearance and colour while hybrid derivative *Pavizham* scored highest value for flavour, texture and taste.

There was a significant difference among the rice varieties in the quality attribute texture. The mean scores ranged between 1.80 to 4.70. The highest score was noticed in variety No. 41 *(Kattamodan)* while the lowest score was observed in variety No.21 *(Red Triveni)*. Eight hybrid derivatives, twelve traditional varieties and one other improved variety were found to be on par with *Kattamodan* where as four hybrid derivatives and two traditional varieties were found to be on par with *Red Triveni*. In general, other improved varieties were found to have higher score (4.00) when compared to hybrid derivatives (3.25) and traditional varieties (3.64).

Significant ~~[illegible]~~ differences were noticed among the rice varieties for taste. Other improved varieties were found to have higher mean scores (3.75) when compared to hybrid derivatives (3.15) and traditional varieties (3.41). The highest score (4.40) was noticed in *Aryan* while the lowest score (1.40) in *CSRC collection*. Eleven hybrid derivatives, thirteen traditional varieties and two other improved varieties were found to be on par with *Aryan* where as eight hybrid derivatives were found to be on par with *CSRC collection* and found unsuitable for the preparation of *iddli*.

The overall acceptability of the different rice varieties also differed significantly. The highest mean score (4.20) was noticed in *Aruna* since it has scored highest for quality attributes like appearance and colour while the lowest score (1.86) was observed in *CSRC collection*. In general, other improved varieties were found to have higher mean score (3.86) when compared to hybrid derivatives (3.23) and traditional varieties (3.49). Ten hybrid derivatives, sixteen traditional varieties and two other improved varieties were found to be on par with *Aruna*.

Hybrid derivatives such as *Annapoorna, Aruna, Jayathi, Neeraja, Nila, Pavizham, Reshmi, Swarnaprabha, Swarnamodan, Vyttila-1* and *Vyttila-3* and traditional varieties such as *Aryan, Chenkayama, Cheriya Aryan, Chitteni, Chuvannamodan, Chuvannari Thavalakannan, Elappapoochemban, Kattamodan, Kavunginpoothala, Ponnaryan, Thekken, Thekkencheera, Vadakken Chitteni, Vellari, Veluthavattan, Veluthari Thavalakannan* and other improved varieties such as *CO-25* and *Mashuri* were found to be highly suitable and varieties such as *CSRC collection, Jyothi, Onam, Red Triveni, Chettivirippu and Kuruwa* were found unsuitable as far as this preparation is concerned.

4.3.3 Fermenting and steaming *(Iddli)* (Table 8)

The mean score obtained for appearance was found to be significantly different for different rice varieties. The highest score (4.40) was noticed in variety No. 2 *(Aruna).* Eight hybrid derivatives, twelve traditional varieties and two other improved varieties were found to be on par with the above variety. The mean score obtained was found to be in the range of 2.10 to 4.40 . The lowest score was noticed in variety No.7 *(CSRC collection).* Six hybrid derivatives and two traditional varieties were found to be on par with this variety. Other improved varieties were found to have highest score (4.00) when compared to hybrid (3.33) and traditional varieties (3.53).

A significant difference among the varieties were also observed for the quality attribute colour. The mean score obtained was found to be in the range of 1.70 to 4.50. In general, other improved varieties were found to have higher score (3.90) when compared to hybrid derivatives (3.19) and traditional varieties (3.38). The highest score was observed for *Aruna* where as the lowest score was obtained by *CSRC collection.* Six hybrid derivatives, seven traditional varieties and one other improved varieity were found to be on par with *Aruna* where as four hybrid derivatives and two traditional varieties were found to be on par with *CSRC collection.* The low mean scores for varieties such as *Jyothi, Makom, Onam, Red Triveni, Kuruwa* and *Chettivirippu* were due to reddish colour.

Among the different rice varieties the mean scores obtained for quality attribute flavour differed significantly. The mean scores ranged between 1.80 *(CSRC collection)* to 4.20 (variety No. 18 and 33) *(Nila* and *Aryan).* Other improved varieties were found to have higher scores (3.65) when compared to traditional varieties (3.45) and hybrid derivatives (3.27). Fourteen hybrid derivatives, seventeen traditional varieties and two other improved varieties were found to be on par with *Nila* and *Aryan*. Similarly three hybrid derivatives were found to be on par with *CSRC collection.*

Table 8 Quality attributes of parboiled rice varieties due to fermenting and steaming

		Quality attributes (mean scores)					
Sl.No.	Variety	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hybrid derivatives							
1.	Annapoorna	3.60	2.80	3.60	3.90	4.10	3.60
2.	Aruna	4.40	4.50	3.90	3.90	4.30	4.20
3.	Asha	3.20	3.40	2.80	3.00	2.70	3.02
4.	Bhadra	2.40	3.00	3.10	3.20	3.30	3.00
5.	Bharathy	3.40	3.80	3.70	3.10	3.10	3.42
6.	Bhagya	3.60	3.00	3.00	2.90	3.00	3.10
7.	CSRC collection	2.10	1.70	1.80	2.30	1.40	1.86
8.	Dhanya	3.50	3.30	3.40	2.80	3.10	3.22
9.	Hraswa	3.00	3.00	3.30	2.90	2.90	3.02
10.	Jaya	3.60	3.60	3.20	2.70	2.80	3.18
11.	Jayathi	3.80	3.80	3.70	4.10	3.80	3.84
12.	Jyothi	2.30	1.90	2.30	3.00	2.00	2.30
13.	Kanakom	2.80	2.60	2.90	2.80	2.60	2.74
14.	Karthika	3.50	3.60	3.50	3.60	3.70	3.58
15.	Lakshmi	3.00	2.80	3.10	2.50	2.90	2.86
16.	Makom	2.70	2.20	2.70	2.60	2.70	2.58
17.	Neeraja	4.00	3.80	3.60	4.10	3.70	3.84
18.	Nila	3.70	3.90	4.20	3.30	3.40	3.70
19.	Onam	2.20	2.10	2.20	2.20	2.20	2.18
20.	Pavizham	4.30	4.40	3.50	4.20	3.40	3.96
21.	Red Triveni	2.70	2.00	2.40	1.80	1.70	2.12
22.	Remya	3.20	2.80	3.00	2.20	2.60	2.76

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
23.	Reshmi	4.20	4.10	3.90	4.40	3.80	4.08
24.	Sabari	2.30	2.50	3.00	2.60	2.20	2.52
25.	Sagara	3.60	3.40	3.20	3.50	3.60	3.46
26.	Swarnaprabha	3.50	3.40	4.10	4.20	4.10	3.86
27.	Swarnamodan	3.70	3.90	3.90	4.30	4.30	4.02
28.	Triveni	3.40	3.00	3.60	3.50	3.80	3.46
29.	Vyttila-1	4.10	3.70	4.00	4.10	3.80	3.94
30.	Vyttila-3	4.10	3.70	3.90	4.00	3.70	3.88
	Mean	**3.33**	**3.19**	**3.27**	**3.25**	**3.15**	**3.23**
Traditional/local varieties							
31.	Aruvakkari	3.40	2.80	3.20	3.00	3.30	3.14
32.	Aryankali	3.60	3.40	3.60	3.20	3.10	3.38
33.	Aryan	3.30	3.90	4.20	4.30	4.40	4.02
34.	Chenkayama	3.80	3.70	3.90	4.40	3.60	3.88
35.	Cheriya Aryan	4.00	3.60	3.80	4.10	3.80	3.86
36.	Chettivirippu	2.30	2.20	2.70	1.90	2.10	2.24
37.	Chitteni	4.00	4.00	3.60	4.20	3.70	3.90
38.	Chuvannamodan	4.20	3.70	3.80	4.00	3.90	3.92
39.	Chuvannari Thavalakannan	3.60	3.40	3.50	4.20	4.00	3.74
40.	Elappapoochemban	3.80	3.40	3.30	3.90	3.80	3.64
41.	Kattamodan	4.10	3.80	3.80	4.70	3.70	4.02
42.	Kutticheradi	2.90	2.90	3.20	2.80	2.70	2.90
43.	Kuruwa	2.70	2.10	2.60	2.20	2.30	2.38
44.	Kavunginpoothala	3.60	3.70	3.80	4.60	4.00	3.94
45.	Navara	2.90	3.10	3.10	3.60	3.00	3.10
46.	Pavizhachembavu	3.20	2.90	3.10	3.10	2.90	3.04

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
47.	Thrissur local-1	3.14	3.40	3.40	3.80	3.20	3.42
48.	Ponnaryan	4.20	3.70	3.60	4.30	4.20	4.00
49.	Sinduram	2.90	2.90	3.30	2.80	2.60	2.90
50.	Thekken	4.20	3.90	3.90	4.10	3.80	3.98
51.	Thekkencheera	4.10	3.80	3.90	3.70	3.50	3.80
52.	Teena	3.20	3.00	3.20	3.00	2.70	3.02
53.	Vadakken Chitteni	3.60	3.40	3.70	3.90	3.70	3.66
54.	Vellari	3.90	3.70	3.60	4.00	4.00	3.84
55.	Veluthavattan	3.80	3.90	3.60	4.50	4.00	3.96
56.	Veluthari Thavalakannan	4.20	4.20	3.80	4.40	4.10	4.14
57.	Thrissur local-2	2.90	2.90	3.40	2.90	3.20	3.06
58.	Aranmula local	3.20	3.20	2.80	2.20	2.20	2.72
	Mean	**3.53**	**3.38**	**3.45**	**3.64**	**3.41**	**3.49**
Other improved/market varieties							
59.	CO-25	4.00	3.50	3.60	4.10	3.80	3.80
60.	Mashuri	4.00	4.30	3.70	3.90	3.70	3.92
	Mean	**4.00**	**3.90**	**3.65**	**4.00**	**3.75**	**3.86**
	Gross Mean	**3.44**	**3.30**	**3.38**	**3.46**	**3.29**	**3.38**
	F	4.431**	5.889**	3.048 **	8.159**	6.199 **	7.661**
	SE	0.281	0.270	0.298	0.270	0.285	0.217
	CD	0.780	0.749	0.828	0.749	0.792	0.603

**Significant at 1% level

Traditional varieties such as *Chenkayama*, *Chuvannamodan and Elappapoochemban* were suitable for the preparation cooked rice either in raw or parboiled form were also found suitable for the preparation of *iddli*. While among six hybrid derivatives identified as suitable for cooked rice only *Aruna* and *Pavizham* were suitable for this preparation. Other varieties unsuitable for iddli may be due to low scores obtained in quality attributes such as flavour, taste, texture in the case of varieties *Asha* and *Kanakom* and appearance colour and texture in the case of varieties *Bhadra* and *Karthika*. The unsuitable variety *Kavunginpoothala* for cooked rice (parboiled) and *Chuvannari Thavalakannan* for cooked rice (raw) were found to be suitable for the preparation *iddli*.

4.3.4 Fermenting and shallow frying (*Dosa*) (Table 9)

The mean score obtained for appearance of the preparation dosa using raw rice was found to be significantly different for different rice varieties. Traditional varieties were found to have higher mean score (3.69) when compared to hybrid derivatives (3.33) and other improved varieties (3.55). The mean scores ranged between 1.80 to 4.70. The highest mean score was noticed in *Elappapoochemban* while the lowest in *CSRC collection*. Nine hybrid derivatives and ten traditional varieties were found to be on par with *Elappapoochemban* where as three hybrid derivatives and two traditional varieties were found to be on par with *CSRC collection*.

There was a significant difference among the rice varieties in the quality attribute colour. Traditional varieties were found to have higher score (3.56) when compared to hybrid derivatives (3.17) and other improved varieties (3.45). The mean scores ranged between 1.30 *(CSRC collection)* to 4.70 *(Elappapoochemban)*. Five hybrid derivatives and eight traditional varieties were found to be on par with *Elappapoochemban* where as one hybrid derivative was also found to be on par with *CSRC collection*.

A significant difference among the varieties were also observed for the quality attribute flavour. The mean scores ranged between 2.10 to 4.30. Other improved varieties were found to have higher mean scores (4.00) when compared to hybrid derivatives (3.38) and the traditional varieties (3.51). The highest score was noticed in *Elappapoochemban* while the lowest in *CSRC collection*. Thirteen hybrid derivatives, sixteen traditional varieties and two other improved varieties were found to be on par with *Elappapoochemban* where as four hybrid derivatives and five traditional varieties were also found to be on par with *CSRC collection.*

Among the different rice varieties the mean score obtained for quality attribute texture differed significantly. The mean score was found to be in the range of 2.40 to 4.30. Other improved varieties were found to have higher scores (4.00) when compared to hybrid derivatives (3.47) and traditional varieties (3.56). The highest mean score was observed for variety *No. 23 Reshmi and variety No. 28 Triveni* and lowest mean score for variety No. 16 *Makom*. Ten hybrid derivatives, twenty traditional varieties and two other improved varieties were found to be on par with variety *Triveni*. Fourteen hybrid derivatives and eight traditional varieties were also found to be on par with *Makom.*

Significant differences were observed among the varieties in their taste. Other improved varieties were found to have higher mean scores (3.75) when compared to traditional varieties (3.61) and hybrid derivatives (3.24). The mean scores ranged between 1.60 to 4.30. The highest score was noticed in variety No. 41 *(Kattamodan)* while the lowest in *CSRC collection.* Thirteen hybrid derivatives, nineteen traditional varieties and two other improved varieties were found to be on par with *Kattamodan* where as four hybrid derivatives and one traditional variety were found to be on par with *CSRC collection.*

A significant difference in the overall acceptability was also observed among the different rice varieties. The mean score ranged between 1.94 to 4.38. Other improved varieties were found to have higher mean scores (3.75) when compared to hybrid derivatives (3.27) and traditional varieties (3.56). The highest mean score (4.38) was observed in *Elappapoochemban* while the lowest in *CSRC collection.* Ten hybrid derivatives, twelve traditional varieties and one other improved variety were found to be on par with *Elappapoochemban.*

Table 9 Quality attributes of raw rice varieties due to fermenting and shallow frying.

Sl.No.	Variety	Quality attributes (mean scores)					
		Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hybrid derivatives							
1.	Annapoorna	3.30	3.10	3.70	4.00	3.90	3.60
2.	Aruna	4.60	4.50	3.90	4.00	4.00	4.20
3.	Asha	2.50	2.80	3.20	2.70	3.00	2.84
4.	Bhadra	2.80	3.20	3.20	3.20	3.10	3.10
5.	Bharathy	3.10	3.00	3.70	3.50	3.20	3.30
6.	Bhagya	2.80	2.90	3.10	3.00	2.90	2.94
7.	CSRC collection	1.80	1.30	2.10	3.00	1.60	1.96
8.	Dhanya	4.00	4.00	3.20	3.90	3.50	3.72
9.	Hraswa	4.10	3.70	3.90	3.50	3.90	3.82
10.	Jaya	3.80	3.70	3.00	3.10	3.00	3.32
11.	Jayathi	3.80	3.70	4.00	4.20	3.80	3.90
12.	Jyothi	3.00	2.60	3.10	3.10	3.00	2.96
13.	Kanakom	2.90	2.90	2.50	2.60	2.10	2.60
14.	Karthika	2.60	2.40	3.30	2.90	3.30	2.90
15.	Lakshmi	2.60	2.60	3.20	2.70	2.90	2.80
16.	Makom	2.00	1.90	2.60	2.40	2.50	2.28
17.	Neeraja	3.80	3.70	4.00	4.10	4.10	3.94
18.	Nila	3.50	3.70	3.80	3.60	3.70	3.66
19.	Onam	2.60	2.30	3.00	2.90	2.40	2.64
20.	Pavizham	3.80	3.70	3.20	3.30	2.90	3.38
21.	Red Triveni	2.90	2.30	2.40	2.70	2.70	2.60
22.	Remya	2.10	2.10	2.60	2.40	2.40	2.32

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
23.	Reshmi	4.50	4.20	4.10	4.30	4.20	4.26
24.	Sabari	2.70	2.30	3.10	3.00	2.40	2.70
25.	Sagara	3.30	3.00	3.40	3.10	3.20	3.20
26.	Swarnaprabha	4.60	4.40	3.90	3.70	3.80	4.08
27.	Swarnamodan	4.00	3.80	3.90	3.90	3.80	3.88
28.	Triveni	4.30	4.30	4.20	4.30	4.20	4.26
29.	Vyttila-1	4.00	3.70	4.00	4.10	3.90	3.94
30.	Vyttila-3	4.00	3.50	4.00	3.80	4.00	3.86
	Mean	**3.33**	**3.17**	**3.38**	**3.47**	**3.24**	**3.27**
Traditional/local varieties							
31.	Aruvakkari	3.20	3.20	3.50	3.70	3.60	3.44
32.	Aryankali	3.20	2.80	3.00	3.00	3.20	3.04
33.	Aryan	4.30	4.40	4.10	3.90	3.90	4.12
34.	Chenkayama	4.60	4.50	4.20	4.20	4.20	4.34
35.	Cheriya Aryan	3.60	3.30	3.70	3.80	3.90	3.66
36.	Chettivirippu	2.60	2.10	2.70	2.30	2.40	2.42
37.	Chitteni	4.50	4.50	4.10	3.90	3.80	4.16
38.	Chuvannamodan	4.00	3.60	3.70	3.90	3.90	3.82
39.	Chuvannari Thavalakannan	3.20	3.00	3.60	3.80	4.00	3.52
40.	Elappapoochemban	4.70	4.70	4.30	4.00	4.20	4.38
41.	Kattamodan	4.60	4.40	4.20	3.90	4.30	4.28
42.	Kutticheradi	4.00	3.80	3.70	3.70	3.90	3.82
43.	Kuruwa	2.80	2.50	2.60	2.70	2.60	2.64
44.	Kavunginpoothala	4.50	4.60	3.90	4.00	3.90	4.18
45.	Navara	2.20	2.10	2.60	2.90	2.90	2.54
46.	Pavizhachembavu	2.90	2.60	2.90	2.80	2.90	2.82

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
47.	Thrissur local-1	4.10	4.10	3.60	3.80	4.00	3.92
48.	Ponnaryan	3.70	3.80	3.70	3.90	3.90	3.80
49.	Sinduram	3.90	3.60	3.50	3.60	3.90	3.70
50.	Thekken	3.00	3.20	3.60	3.80	3.70	3.46
51.	Thekkencheera	3.50	3.60	3.40	3.70	3.80	3.60
52.	Teena	3.50	3.20	3.20	3.10	3.00	3.20
53.	Vadakken Chitteni	3.60	3.60	3.60	3.70	3.90	3.68
54.	Vellari	4.50	4.40	3.90	3.70	3.70	4.04
55.	Veluthavattan	4.40	4.20	4.00	4.10	3.90	4.12
56.	Veluthari Thavalakannan	3.80	3.80	3.60	3.70	4.00	3.78
57.	Thrissur local-2	2.50	2.30	2.70	2.90	3.30	2.74
58.	Aranmula local	3.70	3.70	2.70	3.00	2.50	3.12
	Mean	**3.69**	**3.56**	**3.51**	**3.56**	**3.61**	**3.56**
Other improved/market varieties							
59.	CO-25	3.70	3.60	4.10	4.20	4.00	3.92
60.	Mashuri	3.40	3.30	3.90	3.80	3.50	3.58
	Mean	**3.55**	**3.45**	**4.00**	**4.00**	**3.75**	**3.75**
	Gross Mean	**3.50**	**3.36**	**3.46**	**3.48**	**3.44**	**3.45**
	F	8.929 **	9.327**	3.864**	3.744**	4.623**	7.893**
	SE	0.252	0.262	0.278	0.284	0.295	0.219
	CD	0.699	0.727	0.772	0.789	0.820	0.609

**Significant at 1% level

Out of sixty varieties, eleven hybrid derivatives and sixteen traditional varieties and two other improved varieties were found suitable for *iddli*. Of these only eight hybrid derivatives such as *Aruna, Jayathi, Neeraja, Reshmi, Swarnaprabha, Swarnamodan, Vyttila-1, Vyttila-3* and eleven traditional varieties such as *Aryan, Chenkayama, Chitteni, Chuvannamodan, Elappapoochemban, Kattamodan, Ponnaryan, Vellari, Veluthavattan, Veluthari Thavalakannan, Kavunginpoothala* and one other improved variety *CO-25* were found to be suitable for *dosa*. In addition to this two hybrid derivatives such as *Hraswa, Triveni* and *two traditional varieties such as Kutticheradi and Thrissur local-1* were also found ideal for *dosa*.

Varieties such as *CSRC collection, Makom, Remya, Chettivirippu* and *Navara* were found to be unsuitable for the above preparation.

Varieties such as *Chenkayama, Chuvannamodan* and *Elappapoochemban*, suitable for the preparation cooked rice (either in raw or parboiled form) and *iddli* were also found to be suitable for this preparation.

4.3.5 Powdering, roasting and steaming *(Puttu)* (Table 10)

The mean score obtained for appearance of the preparation *puttu* using raw rice was found to be significantly different for different rice varieties. Other improved varieties were found to have higher mean scores (4.35) when compared to hybrid derivatives (3.71) and traditional varieties (3.90). The mean scores ranged between 1.80 to 4.80. The highest mean score was noticed in variety No. 41 *(Kattamodan)* while the lowest in variety No. 7 *(CSRC collection)*. Ten hybrid derivatives, eleven traditional varieties and two other improved varieties were found to be on par with *Kattamodan*. No other variety was found to be on par with *CSRC collection* as far as appearance is concerned.

A significant difference among the varieties were also observed for the quality attribute colour. The mean score ranged between 1.60 to 4.80. Other improved varieties were found to have higher mean score (4.15) when compared to hybrid derivatives (3.61) and traditional varieties (3.88). The highest mean score was observed in variety No.44 *(Kavunginpoothala)* while the lowest in *CSRC collection*. Seven hybrid derivatives, seven traditional varieties and one other improved variety were found to be on par with

Kavunginpoothala where as only one hybrid derivative was found to be on par with *CSRC collection.*

There was a significant difference among the rice varieties in the quality attribute flavour. Other improved varieties were found to have higher score (3.90) when compared to hybrid derivatives (3.43) and traditional varieties (3.65). The highest score (4.70) was noticed in variety No. 55 *(Veluthavattan)* while the lowest (1.20) in variety *CSRC collection*. Seven hybrid derivatives and four traditional varieties were found to be on par with *Veluthavattan*. No other variety was found to be on par with *CSRC collection.*

Among the different rice varieties the mean score obtained for the quality attribute texture differed significantly. Other improved varieties were found to have higher mean score (3.80) when compared to hybrid derivatives (3.36) and traditional varieties (3.64). The highest mean score (4.50) was observed in variety *Veluthavattan* while the lowest (2.10) in variety *CSRC collection.* Seven hybrid derivatives, twelve traditional varieties and one other improved variety were found to be on par with *Veluthavattan* where as five hybrid derivatives and three traditional varieties were found to be on par with *CSRC collection.*

Significant ~~cultural~~ differences were observed among the different rice varieties for the quality attribute taste. Other improved varieties were found to have higher mean score (3.85) when compared to hybrid derivatives (3.54) and traditional varieties (3.72). The highest mean score (4.70) was noticed in variety No. 49 *(Sinduram)* while the lowest (1.80) in variety *CSRC collection.* Five hybrid derivatives, nine traditional varieties and one other improved variety were found to be on par with *Sinduram* where as one hybrid derivative and one traditional variety were found to be on par with *CSRC collection.*

The overall acceptability of the preparation also revealed significant differences among different rice varieties. Other improved varieties were found to have higher mean score (4.01) when compared to hybrid derivatives (3.54) and traditional varieties (3.76). The highest mean score (4.56) was observed in *Veluthavattan* while the lowest score (1.72) in variety *CSRC collection* . Five hybrid derivatives, six traditional varieties and one other improved variety were found to be on par with *Veluthavattan.*

Table 10 Quality attributes of raw rice varieties due to powdering, roasting and steaming

Sl.No.	Variety	Quality attributes (mean scores)					
		Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hybrid derivatives							
1.	Annapoorna	3.80	3.70	4.10	4.00	4.40	4.00
2.	Aruna	4.10	3.90	4.00	3.50	3.80	3.86
3.	Asha	3.00	3.20	2.90	3.90	3.30	3.26
4.	Bhadra	3.20	3.10	2.70	3.60	3.40	3.20
5.	Bharathy	3.50	3.90	3.40	2.70	3.30	3.36
6.	Bhagya	3.20	3.40	3.80	3.30	3.70	3.48
7.	CSRC collection	1.80	1.60	1.30	2.10	1.80	1.72
8.	Dhanya	3.80	3.50	3.30	2.90	3.20	3.34
9.	Hraswa	3.90	3.70	3.60	3.60	4.50	3.86
10.	Jaya	3.40	3.60	3.00	2.90	3.30	3.24
11.	Jayathi	4.20	4.20	4.10	3.50	3.80	3.96
12.	Jyothi	3.20	2.90	2.80	2.60	2.50	2.80
13.	Kanakom	3.90	4.00	3.90	4.00	3.90	3.94
14.	Karthika	4.10	4.20	3.90	3.70	3.70	3.92
15.	Lakshmi	4.00	3.70	3.80	3.60	3.80	3.78
16.	Makom	4.00	3.90	3.20	3.40	3.50	3.60
17.	Neeraja	4.70	4.20	3.80	3.80	3.90	4.08
18.	Nila	3.90	3.60	4.00	4.10	4.10	3.94
19.	Onam	3.00	2.60	3.00	2.50	2.90	2.80
20.	Pavizham	3.60	3.60	4.10	3.50	3.50	3.66
21.	Red Triveni	2.60	2.20	2.20	2.20	2.60	2.36

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
22.	Remya	3.60	3.60	3.20	3.60	3.60	3.52
23.	Reshmi	3.40	3.70	3.40	3.50	3.70	3.54
24.	Sabari	2.80	2.50	2.00	2.40	3.10	2.56
25.	Sagara	4.20	3.80	3.30	3.70	3.50	3.70
26.	Swarnaprabha	4.60	4.70	3.80	3.30	3.30	3.94
27.	Swarnamodan	4.70	4.70	3.90	3.70	3.60	4.12
28.	Triveni	4.10	3.90	3.90	3.80	3.70	3.88
29.	Vyttila-1	4.80	4.50	4.30	4.20	4.40	4.44
30.	Vyttila-3	4.30	4.30	4.40	3.80	4.40	4.24
	Mean	**3.71**	**3.61**	**3.43**	**3.36**	**3.54**	**3.54**
Traditional/local varieties							
31.	Aruvakkari	3.30	3.50	3.60	3.40	4.00	3.56
32.	Aryankali	3.20	2.90	3.10	2.60	3.30	3.02
33.	Aryan	3.80	3.70	3.80	4.10	3.80	3.84
34.	Chenkayama	4.80	4.70	3.80	3.60	3.60	4.10
35.	Cheriya Aryan	3.90	3.80	3.40	3.80	3.60	3.70
36.	Chettivirippu	3.00	2.70	2.60	2.40	2.50	2.64
37.	Chitteni	4.30	4.70	4.10	3.90	4.00	4.20
38.	Chuvannamodan	3.70	4.00	4.10	3.60	3.80	3.84
39.	Chuvannari Thavalakannan	4.20	3.60	3.70	3.60	3.50	3.72
40.	Elappapoochemban	3.60	3.80	3.80	3.30	3.40	3.58
41.	Kattamodan	4.80	4.60	4.40	4.20	4.20	4.44
42.	Kutticheradi	3.80	3.60	3.80	4.00	4.10	3.86
43.	Kuruwa	3.10	3.10	2.20	2.30	2.40	2.62
44.	Kavunginpoothala	4.50	4.80	4.60	4.40	4.10	4.48
45.	Navara	3.90	3.90	3.60	4.10	3.80	3.86

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
46.	Pavizhachembavu	3.60	3.80	3.60	3.80	3.60	3.68
47.	Thrissur local-1	4.50	4.40	3.80	3.80	4.30	4.16
48.	Ponnaryan	4.20	3.90	3.50	3.30	3.30	3.64
49.	Sinduram	3.50	3.70	3.80	3.80	4.70	3.90
50.	Thekken	3.50	3.50	3.70	3.40	3.90	3.60
51.	Thekkencheera	4.10	3.90	3.40	3.40	3.50	3.66
52.	Teena	3.40	3.70	3.30	3.60	3.80	3.56
53.	Vadakken Chitteni	4.10	4.20	3.60	3.70	3.40	3.80
54.	Vellari	4.10	4.30	4.00	4.20	4.20	4.16
55.	Veluthavattan	4.50	4.60	4.70	4.50	4.50	4.56
56.	Veluthari Thavalakannan	4.40	4.00	3.70	3.80	3.70	3.92
57.	Thrissur local-2	4.00	4.00	3.70	3.90	4.10	3.94
58.	Aranmula local	3.30	3.30	2.80	3.30	3.00	3.14
	Mean	**3.90**	**3.88**	**3.65**	**3.64**	**3.72**	**3.76**
Other improved/market varieties							
59.	CO-25	4.60	4.40	3.90	4.40	4.20	4.30
60.	Mashuri	4.10	3.90	3.90	3.20	3.50	3.72
	Mean	**4.35**	**4.15**	**3.90**	**3.80**	**3.85**	**4.01**
	Gross Mean	**3.82**	**3.76**	**3.55**	**3.51**	**3.63**	**3.66**
	F	4.642**	5.093**	5.659**	4.566 **	4.028**	6.673**
	SE	0.279	0.280	0.268	0.266	0.279	0.211
	CD	0.773	0.778	0.744	0.739	0.776	0.586

**Significant at 1% level

Hybrid derivatives such as *Annapoorna, Neeraja, Swarnamodan, Vyttila-1, Vyttila-3 and traditional varieties such as chenkayama, Chitteni, Kattamodan, Kavungin poothala, Thrissur local-1, Vellari, Veluthavattan* and other improved variety *CO-25* were found to be highly suitable and variety *CSRC collection* was found to be unsuitable as far as this preparation is concerned.

Variety *Chenkayama* suitable for cooked rice, (raw and parboiled) *iddli, dosa* was also found to be highly suitable for *puttu* preparation.

Among the sixty rice varieties studied only four hybrid derivatives *(Neeraja, Swarnamodan, Vyttila-1 and Vyttila-3)* and six local varieties *(Chenkayama, Chitteni, Kattamodan, Kavungin poothala, Vellari* and *Veluthavattan)* and other improved variety *CO-25* were found suitable for all the three preparations. *Annapoorna* was found suitable for *iddli* and *puttu* and *Trichur local-1* was found suitable for *dosa* or *puttu*. Among other improved varieties *CO-25* was also found suitable for *dosa* or *puttu*.

4.3.6 Powdering, roasting and boiling *(Kozhukkatta)* (Table No. 11)

The mean score obtained for appearance of the preparation *kozhukkatta* using raw rice was found to be significantly different for different rice varieties. Other improved varieties were found to have higher mean score (3.70) when compared to hybrid derivatives (3.36) and traditional varieties (3.64). The highest mean score (4.50) was noticed in variety No. 48 *(Ponnaryan)* while the lowest score (1.80) in variety No. 7 *(CSRC collection)*. Eight hybrid derivatives, twelve traditional varieties and one other improved variety were found to be on par with *Ponnaryan* where as one hybrid derivative and one traditional variety were found to be on par with *CSRC collection*.

There was a significant difference among the rice varieties in the quality attribute colour. Traditional varieties were found to have higher mean score (3.58) when compared to hybrid derivatives (3.44) and other improved varieties (3.50). The highest mean score (4.40) was noticed in variety No. 26 *(Swarnaprabha)* while the lowest score (1.30) in variety *CSRC collection*. Eight hybrid derivatives, thirteen traditional varieties and one other improved variety were found to be on par with *Swarnaprabha* where as no other variety was found to be on par with *CSRC collection*.

A significant difference was noticed among the rice varieties in the quality attribute flavour. Other improved varieties were found to have higher mean scores (3.65) when compared to traditional varieties (3.38) and hybrid derivatives (3.42). The highest mean score (4.30) was observed in variety No. 29 *(Vyttila-1)* while the lowest (1.00) in variety *CSRC collection*. Fifteen hybrid derivatives, fifteen traditional varieties and one other improved variety were found to be on par with *CSRC collection*.

Significant differences were noticed among different rice varieties in the quality attribute texture. Traditional varieties were found to have higher mean scores (3.33) when compared to hybrid derivatives (3.18) and other improved varieties (3.25). The highest score (4.20) was observed for *Vyttila-1* while the lowest (1.40) in *CSRC collection*. Eleven hybrid derivatives, fifteen traditional varieties and one other improved variety were found to be on par with *Vyttila-1* where as one hybrid derivative was found to be on par with *CSRC collection*.

Significant [illegible] differences were observed among different rice varieties in the quality attribute taste. The mean score ranged between. 1.10 to 4.40. Other improved varieties were found to have higher mean scores (3.60) when compared to hybrid derivatives (3.34) and traditional varieties (3.46). The highest score was observed in *Vyttila-1* while the lowest in *CSRC collection*. Four hybrid derivatives, nine traditional varieties and one other improved variety were found to be on par with *Vyttila-1*.

The overall acceptability of the preparation also revealed a significant difference among the rice varieties. Other improved varieties were found to have higher mean score (3.54) when compared to hybrid derivatives (3.35) and traditional varieties (3.47). The highest mean score (4.32) was observed in *Vyttila-1* while the lowest (1.32) in *CSRC collection*. Two hybrid derivatives, eight traditional varieties and one other improved variety were found to be on par with *Vyttila-1*.

Hybrid derivatives such as *Swarna Prabha, Vyttila-1, Vyttila-3* and traditional varieties such as *Cheriya Aryan, Chitteni, Kavungin poothala, Thrissur local-1, Ponnaryan, Thekkencheera, Vellari, Veluthari Thavalakannan* and other improved variety *CO-25* were found to be highly acceptable for this preparation. Variety *CSRC collection* was found to be unsuitable for this preparation.

Table 11 Quality attributes of raw rice varieties due to powdering, roasting and boiling.

		Quality attributes (mean scores)					
Sl.No.	Variety	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hybrid derivatives							
1.	Annapoorna	3.20	3.50	3.50	3.30	3.40	3.38
2.	Aruna	2.10	2.70	3.10	2.20	3.10	2.64
3.	Asha	3.30	3.30	3.10	3.50	3.00	3.24
4.	Bhadra	2.60	3.20	3.30	3.20	3.50	3.16
5.	Bharathy	3.40	3.50	3.90	3.20	3.40	3.48
6.	Bhagya	2.80	3.30	3.20	2.90	3.00	3.04
7.	CSRC collection	1.80	1.30	1.00	1.40	1.10	1.32
8.	Dhanya	3.30	3.10	3.30	2.90	3.20	3.16
9.	Hraswa	3.50	3.40	3.60	3.30	3.40	3.44
10.	Jaya	2.80	2.90	3.40	3.40	3.60	3.22
11.	Jayathi	3.80	3.70	3.30	3.20	3.60	3.52
12.	Jyothi	3.70	3.50	3.60	3.80	3.20	3.56
13.	Kanakom	4.10	4.00	3.30	3.30	3.30	3.60
14.	Karthika	4.00	3.80	3.40	3.50	3.60	3.66
15.	Lakshmi	3.70	3.70	3.60	3.00	3.40	3.48
16.	Makom	3.10	3.40	3.90	3.50	3.70	3.52
17.	Neeraja	3.80	4.00	3.50	3.10	3.40	3.56
18.	Nila	3.30	3.00	3.60	2.80	3.30	3.20
19.	Onam	3.60	3.50	3.40	3.10	3.20	3.36
20.	Pavizham	3.00	3.30	3.40	3.40	3.70	3.36
21.	Red Triveni	3.70	3.50	3.70	3.30	3.40	3.52

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
22.	Remya	3.00	3.10	3.00	3.00	2.90	3.00
23.	Reshmi	3.10	3.40	3.60	3.70	3.40	3.44
24.	Sabari	2.90	3.50	3.50	2.90	3.60	3.28
25.	Sagara	2.80	3.40	3.40	2.90	3.30	3.16
26.	Swarnaprabha	4.10	4.40	3.70	3.40	3.90	3.90
27.	Swarnamodan	4.40	4.20	3.50	2.80	3.00	3.58
28.	Triveni	3.10	3.20	3.70	3.30	2.80	3.22
29.	Vyttila-1	4.40	4.30	4.30	4.20	4.40	4.32
30.	Vyttila-3	4.30	4.30	4.10	3.80	4.30	4.16
	Mean	**3.36**	**3.44**	**3.42**	**3.18**	**3.34**	**3.35**
Traditional/local varieties							
31.	Aruvakkari	3.80	3.80	3.90	3.10	3.60	3.64
32.	Aryankali	2.30	2.60	3.20	2.50	2.90	2.70
33.	Aryan	3.30	3.40	3.40	2.80	3.70	3.32
34.	Chenkayama	3.40	3.60	3.50	3.20	3.70	3.48
35.	Cheriya Aryan	3.90	3.60	3.70	3.80	3.90	3.78
36.	Chettivirippu	3.10	3.20	2.60	3.30	2.80	3.00
37.	Chitteni	3.80	3.80	3.60	3.80	3.50	3.70
38.	Chuvannamodan	3.90	3.70	3.50	3.50	3.70	3.66
39.	Chuvannari Thavalakannan	3.90	3.80	3.40	3.10	3.50	3.54
40.	Elappapoochemban	4.20	3.80	3.50	2.90	3.80	3.64
41.	Kattamodan	3.70	3.60	3.30	3.30	3.30	3.44
42.	Kutticheradi	3.40	3.50	3.50	2.90	3.60	3.38
43.	Kuruwa	3.50	3.30	3.50	3.80	3.30	3.48
44.	Kavunginpoothala	4.30	4.20	3.50	3.70	3.50	3.84
45.	Navara	3.50	3.30	3.20	3.40	3.60	3.40

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
46.	Pavizhachembavu	3.10	2.90	2.50	2.90	2.80	2.84
47.	Thrissur local-1	3.90	3.90	3.70	3.60	4.00	3.82
48.	Ponnaryan	4.50	4.20	3.70	3.40	3.60	3.88
49.	Sinduram	3.40	3.50	3.40	3.10	3.50	3.38
50.	Thekken	3.10	3.30	3.40	2.90	3.30	3.20
51.	Thekkencheera	4.00	3.70	3.60	3.60	3.80	3.74
52.	Teena	3.50	3.10	2.80	3.50	3.20	3.22
53.	Vadakken Chitteni	3.30	3.80	3.10	3.20	2.80	3.24
54.	Vellari	4.20	3.80	3.70	3.90	4.10	3.94
55.	Veluthavattan	3.90	4.00	3.70	3.50	3.30	3.68
56.	Veluthari Thavalakannan	4.20	3.80	3.70	3.80	3.60	3.82
57.	Thrissur local-2	3.50	3.40	3.30	3.30	3.80	3.46
58.	Aranmula local	3.20	3.50	2.70	3.40	2.70	3.10
	Mean	**3.64**	**3.58**	**3.38**	**3.33**	**3.46**	**3.47**
Other improved/market varieties							
59.	CO-25	4.10	3.90	3.90	3.40	3.80	3.82
60.	Mashuri	3.30	3.10	3.40	3.10	3.40	3.26
	Mean	**3.70**	**3.50**	**3.65**	**3.25**	**3.60**	**3.54**
	Gross Mean	**3.50**	**3.51**	**3.41**	**3.25**	**3.40**	**3.41**
	F	4.201**	3.187**	2.585 **	2.310 **	2.909 **	3.452**
	SE	0.277	0.281	0.295	0.289	0.277	0.227
	CD	0.769	0.781	0.819	0.803	0.768	0.629

**Significant at 1% level

For all four cereal based preparations, only two hybrid derivatives *(Vyttila-1* and *Vyttila-3)* and three traditional varieties *(Chitteni, Kavungin poothala* and *Vellari)* were found suitable. Excluding ***kozhukkatta***, hybrid derivatives like *Neeraja, Swarnamodan,* and traditional varieties like *Chenkayama, Kattamodan* and *Veluthavattan* were found suitable for the three preparations. While in the case of *Swarnaprabha* it was unsuitable only for *puttu*. *Thrissur local-1* and *CO-25* were found unsuitable only for *Iddli.*

4.3.7. Baking *(Appam)* (Table 12)

The quality attribute appearance of the preparation *appam* differed significantly among rice varieties. Other improved varieties were found to have higer mean score (3.80) when compared to hybrid (3.42) and traditional varieties (3.51). The highest score (4.30) was noticed in variety No. 27 *(Swarnamodan)* while the lowest score (1.50) in variety No. 7 *(CSRC collection)*. Twelve hybrid derivatives, fourteen traditional varieties and two other improved varieties were found to be on par with *Swarnamodan* where as one traditional variety was found to be on par with *CSRC collection.*

Among the different rice varieties the mean score obtained for quality attribute colour differed significantly. The mean score was found to be higher in other improved varieties (3.85) when compared to traditional varieties (3.28) and hybrid derivatives (3.30). The highest score (4.40) was observed in variety No. 44 *(Kavunginpoothala)* while the lowest (1.50) in *CSRC collection.* Nine hybrid derivatives, eight traditional varieties and two other improved varieties were found to be on par with *Kavunginpoothala* where as one traditional variety was found to be on par with *CSRC collection*.

Significant differences among the varieties were also observed for the quality attribute flavour. Other improved varieties were found to have higher mean score (3.45) when compared to hybrid derivatives (3.03) and traditional varieties (3.10). The highest score (3.80) was noticed in variety No.1 *(Annapoorna)* while the lowest (1.00) in *CSRC collection.* Fourteen hybrid derivatives, fourteen traditional varieties and two other improved varieties were found to be on par with *Annapoorna*. No other variety was found to be on par with *CSRC collecion.*

The mean score obtained for the quality attribute texture differed significantly among different rice varieties. Other improved varieties were found to have higher mean score (3.40) when compared to traditional varieties (2.95) and hybrid derivatives (2.98). The highest score (4.10) was noticed in *Annapoorna* while the lowest (1.60) in *CSRC collection.* Five hybrid derivatives, seven traditional varieties and two other improved varieties were found to be on par with *Annapoorna* where as one hybrid derivative and two traditional varieties were found to be on par with *CSRC collection.*

Significant differences were also observed among different rice varieties in the quality attribute taste. The mean of both hybrid and traditional varieties were found to be the same (3.05) where as for other improved varieties it was 3.65. The highest score (4.00) was observed in *Annapoorna* while the lowest (1.00) in *CSRC collection.* Twelve hybrid derivatives, twelve traditional varieties and two other improved varieties were found to be on par with *Annapoorna.* No other variety was found to be on par with *CSRC collection.*

The overall acceptability of the preparation also revealed significant differences among different rice varieties. In general, other improved varieties were found to have higher mean scores (3.63) when compared to hybrid derivatives (3.07) and traditional varieties (3.18). The highest score (3.76) was observed in variety No. 59 *(CO-25)* while the lowest (1.32) in *CSRC collection.* Nineteen hybrid derivatives, sixty traditional varieties and one other improved variety were found to be on par with *CO-25* .

Hybrid derivatives such as *Annapoorna*, *Bhagya, Jayathi, Jyothi, Kanakom, Lakshmi, Makom, Neeraja, Onam, Red Triveni, Remya, Reshmi, Sabari, Sagara*, *Swarnaprabha, Swarnamodan, Triveni, Vyttila-1, Vyttila-3* and traditional varieties such as *Aryan, Chenkayama, Cheriya Aryan, Chettivirippu, Elappapoochemban, Kattamodan, Kuruwa, Kavunginpoothala, Navara, Thrissur local-1, Thekken, Vellari, Veluthavattan, Thrissur local-2, Aranmula local* and other improved varieties such as *Mashuri* and *CO-25* were found to be suitable for the preparation *appam*. Variety *CSRC collection* was found to be unsuitable in this case also.

Varieties *Vyttila-1, Vyttila-3, Kavunginpoothala, Vellari* and *CO-25* were highly suitable for all the five preparations while *Trichur local-1* was unsuitable only for *iddli* and *Veluthavattan* for *kozhukkatta*.

Table 12 Quality attributes of raw rice varieties due to baking

Sl.No.	Variety	Quality attributes (mean scores)					
		Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hybrid derivatives							
1.	Annapoorna	3.90	3.70	3.80	4.10	4.00	3.90
2.	Aruna	3.00	2.70	2.90	2.90	2.80	2.86
3.	Asha	3.10	3.50	2.80	2.70	2.40	2.90
4.	Bhadra	2.90	3.20	2.90	2.80	3.00	2.96
5.	Bharathy	3.00	2.80	2.90	3.50	3.00	3.04
6.	Bhagya	3.40	3.60	3.30	2.80	3.00	3.22
7.	CSRC collection	1.50	1.50	1.00	1.60	1.00	1.32
8.	Dhanya	3.00	3.10	2.40	2.20	2.30	2.60
9.	Hraswa	3.20	2.50	3.20	2.80	3.10	2.96
10.	Jaya	3.10	2.90	2.90	2.60	2.70	2.84
11.	Jayathi	4.10	3.80	3.10	3.00	3.10	3.42
12.	Jyothi	3.50	3.30	3.00	3.10	3.30	3.24
13.	Kanakom	3.70	3.50	2.80	2.70	3.10	3.16
14.	Karthika	3.30	2.80	2.80	2.90	2.90	2.94
15.	Lakshmi	3.60	3.30	3.40	2.80	3.30	3.28
16.	Makom	4.00	3.50	3.00	3.70	3.60	3.56
17.	Neeraja	4.00	3.70	3.20	3.10	3.50	3.50
18.	Nila	2.90	2.90	2.90	2.90	2.90	2.90
19.	Onam	3.40	3.30	3.50	3.10	2.90	3.24
20.	Pavizham	3.40	3.00	3.00	3.00	2.70	3.02
21.	Red Triveni	3.60	3.50	3.60	3.30	3.00	3.40
22.	Remya	3.90	3.70	2.90	3.00	3.20	3.34

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
23.	Reshmi	4.00	3.90	3.60	3.30	3.70	3.70
24.	Sabari	2.90	3.00	2.80	3.50	3.60	3.16
25.	Sagara	3.80	3.80	3.40	3.10	3.30	3.48
26.	Swarnaprabha	4.00	3.80	3.20	2.80	2.80	3.32
27.	Swarnamodan	4.30	4.10	3.30	3.40	3.50	3.72
28.	Triveni	3.90	4.10	3.50	3.40	3.50	3.68
29.	Vyttila-1	3.10	3.20	3.40	2.80	3.30	3.16
30.	Vyttila-3	3.10	3.20	3.60	2.50	3.40	3.16
	Mean	**3.42**	**3.30**	**3.03**	**2.98**	**3.05**	**3.07**
Traditional/local varieties							
31.	Aruvakkari	3.80	3.70	3.70	3.50	3.60	3.66
32.	Aryankali	2.20	1.90	2.50	2.20	2.00	2.16
33.	Aryan	4.10	4.00	3.30	3.10	3.30	3.56
34.	Chenkayama	4.20	4.10	3.30	3.10	3.30	3.60
35.	Cheriya Aryan	2.90	2.90	2.90	2.40	2.70	2.76
36.	Chettivirippu	3.50	2.90	2.80	3.30	3.10	3.12
37.	Chitteni	3.50	3.60	3.60	3.20	3.70	3.52
38.	Chuvannamodan	3.60	3.20	3.10	2.90	3.00	3.16
39.	Chuvannari Thavalakannan	2.90	2.30	3.00	2.50	2.90	2.72
40.	Elapapoochemban	4.00	3.70	2.90	3.30	3.40	3.46
41.	Kattamodan	4.20	3.90	3.20	3.40	3.70	3.68
42.	Kutticheradi	3.20	2.50	2.70	2.70	3.10	2.84
43.	Kuruwa	3.40	3.20	3.30	3.50	3.00	3.28
44.	Kavunginpoothala	4.30	4.40	3.40	3.40	3.20	3.74
45.	Navara	4.10	3.70	2.90	2.80	3.50	3.40
46.	Pavizhachembavu	3.20	2.80	3.10	2.50	2.70	2.86

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
47.	Thrissur local-1	3.80	3.60	3.30	2.80	3.10	3.32
48.	Ponnaryan	3.60	3.30	3.10	2.70	2.70	3.08
49.	Sinduram	3.40	2.60	2.80	2.80	3.20	2.96
50.	Thekken	3.30	3.10	2.90	3.60	3.00	3.18
51.	Thekkencheera	3.00	3.00	2.40	2.20	2.30	2.58
52.	Teena	2.50	2.60	2.80	2.80	2.70	2.68
53.	Vadakken Chitteni	3.40	3.30	3.00	2.20	2.40	2.86
54.	Vellari	3.60	3.60	3.70	3.80	3.80	3.70
55.	Veluthavattan	3.90	3.80	3.50	3.50	3.50	3.64
56.	Veluthari Thavalakannan	3.10	2.70	3.00	2.50	2.40	2.74
57.	Thrissur local-2	3.80	3.40	3.00	2.70	3.30	3.24
58.	Aranmula local	3.90	3.70	3.70	3.10	2.90	3.46
	Mean	**3.51**	**3.28**	**3.10**	**2.95**	**3.05**	**3.18**
Other improved/ market varieities							
59.	CO-25	3.80	3.80	3.40	3.90	3.90	3.76
60.	Mashuri	3.80	3.90	3.50	2.90	3.40	3.50
	Mean	**3.80**	**3.85**	**3.45**	**3.40**	**3.65**	**3.63**
	Gross Mean	**3.48**	**3.30**	**3.09**	**2.98**	**3.07**	**3.19**
	F	4.118 **	1.370 **	2.706**	2.861**	3.313**	4.111**
	SE	0.262	0.269	0.277	0.275	0.288	0.216
	CD	0.726	0.746	0.769	0.762	0.799	0.596

**Significant at 1% level

Another notable point in this context is that seven hybrid derivatives *(Triveni, Kanakom, Lakshmi, Makom, Red Triveni, Sabari* and *Sagara)* and four traditional varieties *(Chettivirippu, Kuruwa, Navara* and *Aranmula local)* were found suitable only for *appam*.

Table 13 presents the influence of different cooking methods on the overall acceptability of the various rice based preparations.

A significant difference was noticed among different rice varieties in the preparation of cooked rice (using raw rice). The variety No. 29 *(Vyttila-1)* obtained the highest score of 4.04 was found to be the best for the above preparation while variety No. 32 *(Aryankali)* was not at all acceptable (2.02). Ten hybrid derivatives and eleven traditional varieties were also found to be suitable for the above preparation.

The overall acceptability of the cooked rice (parboiled) also differed significantly among different rice varieties. The variety No. 20 *(Pavizham)* noticed the highest score (4.26) and was found to be the best one for cooked rice. Seven hybrid derivatives and five traditional varieties were also found to be the best for the above preparation. The variety *CSRC collection* which received a score of 2.44 was found to be not at all acceptable for this preparation.

The overall acceptability of the different rice varieties for the preparation *iddli* differed significantly. The variety No. 2 *(Aruna)* observed a score of (4.20) was found to be most suitable for the preparation *iddli*. Ten hybrid derivatives and sixteen traditional varieties were also found to be suitable for the above preparation.

The overall acceptability of the preparation *dosa* also differed significantly among different rice varieties. The variety No. 40 *(Elappapoochemban)* was found to be best suitable for the above preparation (4.38). Ten hybrid derivatives and twelve traditional varieties were also found to be best suitable for the preparation *dosa*. The variety *CSRC collection* observed the minimum score of 1.96.

Table 13 Influence of different methods of cooking on the overall acceptability of rice based preparations

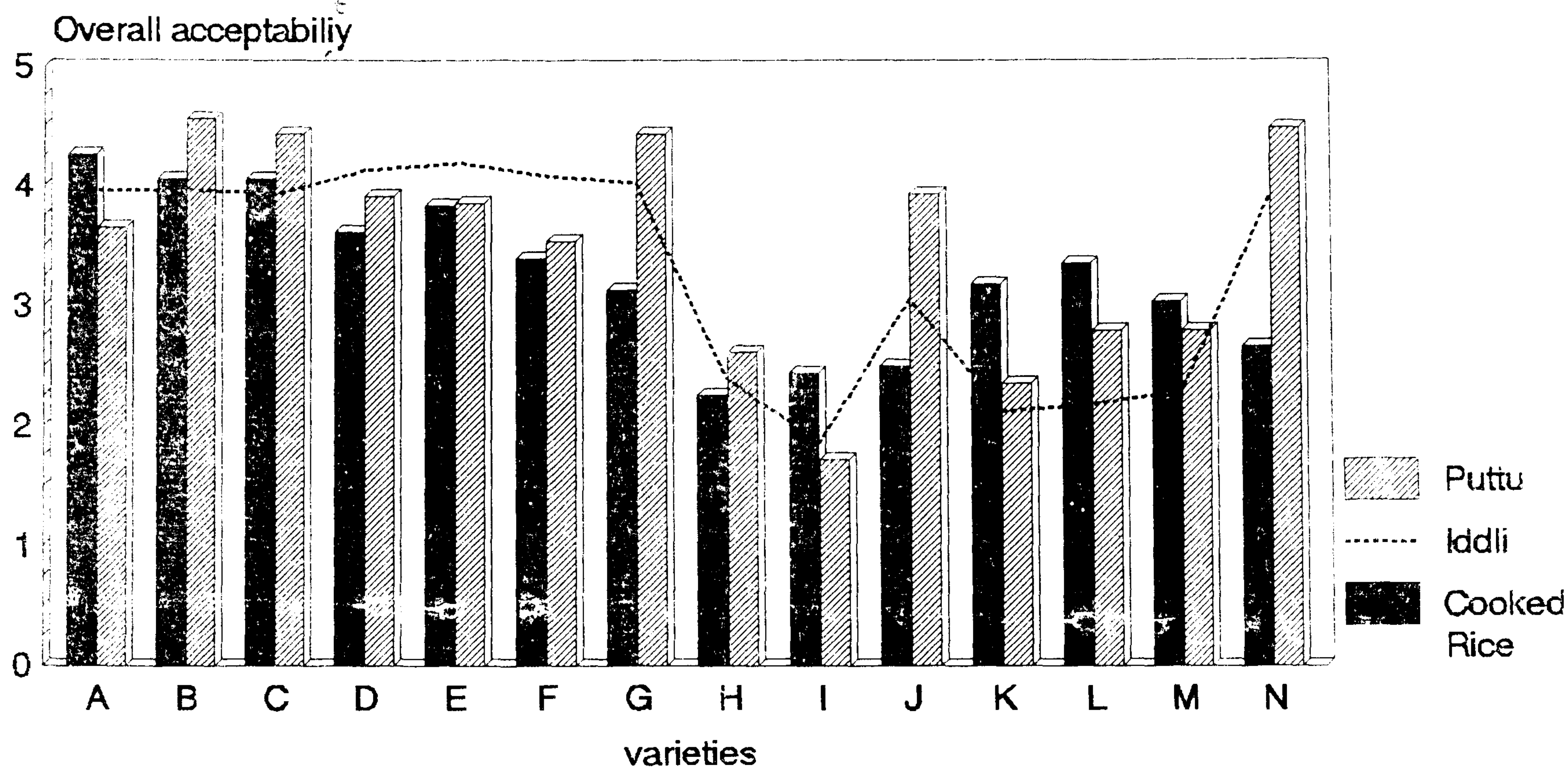
		Mean scores							
Sl. No.	Variety	Cooked rice (Raw)	Cooked rice (P.B)	Iddli	Dosa	Puttu	Kozh.	Appam	Overal l acceptability
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Hybrid derivatives									
1.	Annapoorna	3.42	3.46	3.60	3.60	4.00	3.38	3.90	3.62
2.	Aruna	3.18	3.84	4.20	4.20	3.86	3.84	2.86	3.54
3.	Asha	3.06	3.76	3.02	2.84	3.26	3.24	2.90	3.15
4.	Bhadra	2.80	3.78	3.00	3.10	3.20	3.16	2.96	3.14
5.	Bharathy	3.54	2.66	3.42	3.30	3.36	3.48	3.04	3.26
6.	Bhagya	3.22	3.14	3.10	2.94	3.48	3.04	3.22	3.16
7.	CSRC collection	2.78	2.44	1.86	1.96	1.72	1.32	1.32	1.91
8.	Dhanya	3.12	3.54	3.22	3.72	3.34	3.16	2.60	3.24
9.	Hraswa	3.36	3.50	3.02	3.82	3.86	3.44	2.96	3.42
10.	Jaya	3.18	2.96	3.18	3.32	3.24	3.22	2.84	3.13
11.	Jayathi	3.92	3.34	3.84	3.90	3.96	3.52	3.42	3.70
12.	Jyothi	3.78	3.04	2.30	2.96	2.80	3.56	3.24	3.10
13.	Kanakom	3.64	3.70	2.74	2.60	3.94	3.60	3.16	3.34
14.	Karthika	3.22	3.74	3.58	2.90	3.92	3.66	2.94	3.42
15.	Lakshmi	3.42	3.18	2.86	2.80	3.78	3.48	3.28	3.26
16.	Makom	2.94	3.34	2.58	2.28	3.60	3.52	3.56	3.12
17.	Neeraja	3.74	3.24	3.84	3.94	4.08	3.56	3.50	3.70
18.	Nila	2.92	3.34	3.70	3.66	3.94	3.20	2.90	3.38
19.	Onam	2.98	3.36	2.18	2.64	2.80	3.36	3.24	2.94
20.	Pavizham	3.04	4.26	3.96	3.38	3.66	3.36	3.02	3.53
21.	Red Triveni	3.24	3.18	2.12	2.60	2.36	3.52	3.40	2.92

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
22.	Remya	2.08	3.62	2.76	2.32	3.52	3.00	3.34	2.95
23.	Reshmi	3.54	3.40	4.08	4.26	3.54	3.44	3.70	3.71
24.	Sabari	3.34	3.02	2.52	2.70	2.56	3.28	3.16	2.94
25.	Sagara	3.48	3.16	3.46	3.20	3.70	3.16	3.48	3.38
26.	Swarnaprabha	3.74	3.06	3.86	4.08	3.94	3.90	3.32	3.70
27.	Swarnamodan	3.56	3.52	4.02	3.88	4.12	3.58	3.72	3.77
28.	Triveni	3.06	3.50	3.46	4.26	3.88	3.22	3.68	3.58
29.	Vyttila-1	4.04	4.06	3.94	3.94	4.44	4.32	3.16	3.99
30.	Vyttila-3	4.00	3.94	3.88	3.86	4.24	4.16	3.16	3.89
Traditional/local varieties									
31.	Aruvakkari	3.50	3.08	3.14	3.44	3.56	3.64	3.66	3.43
32.	Aryankali	2.02	3.44	3.38	3.04	3.02	2.70	2.16	2.82
33.	Aryan	3.84	3.46	4.02	4.12	3.84	3.32	3.56	3.74
34.	Chenkayama	3.60	3.72	3.88	4.34	4.10	3.48	3.60	3.82
35.	Cheriya Aryan	2.92	3.68	3.86	3.66	3.70	3.78	2.76	3.48
36.	Chettivirippu	3.16	3.60	2.24	2.42	2.64	3.00	3.12	2.88
37.	Chitteni	3.40	3.06	3.90	4.16	4.20	3.70	3.52	3.71
38.	Chuvannamodan	3.78	3.80	3.92	3.82	3.84	3.66	3.16	3.71
39.	Chuvannari Thavalakannan	2.38	3.26	3.74	3.52	3.72	3.54	2.72	3.27
40.	Elappapoochemban	3.54	3.72	3.64	4.38	3.58	3.64	3.46	3.71
41.	Kattamodan	3.94	3.14	4.02	4.28	4.44	3.44	3.68	3.85
42.	Kutticheradi	2.90	2.98	2.90	3.82	3.86	3.38	2.84	3.24
43.	Kuruwa	3.36	2.26	2.38	2.64	2.62	3.48	3.28	2.86
44.	Kavunginpoothala	3.18	2.66	3.94	4.18	4.48	3.84	3.74	3.72
45.	Navara	3.16	2.60	3.14	2.54	3.86	3.40	3.40	3.16
46.	Pavizhachembavu	2.96	3.22	3.04	2.82	3.68	2.84	2.86	3.06

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
47.	Thrissur local-1	3.76	3.44	3.42	3.92	4.16	3.82	3.32	3.69
48.	Ponnaryan	3.30	3.40	4.00	3.80	3.64	3.88	3.08	3.59
49.	Sinduram	3.14	2.88	2.90	3.70	3.90	3.38	2.96	3.27
50.	Thekken	3.60	3.52	3.98	3.46	3.60	3.20	3.18	3.51
51.	Thekkencheera	3.02	3.36	3.80	3.60	3.66	3.74	2.58	3.39
52.	Teena	2.70	3.04	3.02	3.20	3.56	3.22	2.68	3.06
53.	Vadakken Chitteni	3.68	3.38	3.66	3.68	3.80	3.24	2.86	3.47
54.	Vellari	3.90	3.04	3.84	4.04	4.16	3.94	3.70	3.80
55.	Veluthavattan	3.96	4.06	3.96	4.12	4.56	3.68	3.64	4.00
56.	Veluthari Thavalakannan	3.18	3.62	4.14	3.78	3.92	3.82	2.74	3.60
57.	Thrissur local-2	3.24	2.50	3.06	2.74	3.94	3.46	3.24	3.17
58.	Aranmula local	3.42	3.00	2.72	3.12	3.14	3.10	3.46	3.14
Other improved/market varieties									
59.	CO-25	3.80	3.40	3.80	3.92	4.30	3.82	3.76	3.83
60.	Mashuri	3.54	3.34	3.92	3.58	3.72	3.26	3.50	3.55
	Mean	**3.38**	**3.45**	**3.66**	**3.42**	**3.33**	**3.32**	**3.19**	**3.39**
F	Variety	20.133**							
	Processing	26.603**							
	Variety x Processing	2.956**							
SE	Variety	0.081							
	Processing	0.027							
	Vvariety x Processing	0.215							
CD	Variety	0.226							
	Processing	0.077							
	Variety x Processing	0.599							

**Significant at 1% level

Fig.1 Overall acceptability of selected rice varieties for common rice based preparations



A: Pavizham B: Veluthavattan C: Vyttila-1 D: Veluthari Thavalakkannan E: Aruna F: Reshmi

G: Kattamodan H: Kuruwa I: CSRC Collection J: Thrissur local - 2 K: Red Triveni L: Onam

M: Jyothi N: Kavunginpoothala

Among the different rice varieties, the variety *Vyttila- 1* was found to be most suitable for the preparation *Puttu* (4.44). The lowest score was again observed in *CSRC collection*. Twelve hybrid derivatives and fourteen traditional varieties were found to be unsuitable.

The overall acceptability of different rice varieties for the preparation *kozhukkatta* also differed significantly among the varieties. The variety *(Vyttila-1)* observe the highest score (4.32) was found to be best for the above preparation while the variety *CSRC collection* was found to be least acceptable. Two hybrid derivatives and eight traditional varieties were also found to be suitable for the preparation *kozhukkatta*.

A significant difference in the suitability of different rice varieties in the preparation *appam* could be noticed. The variety No. 1 *(Annapoorna)* noticed the highest score (3.90) and was found to be the best one for the above preparation while the variety *CSRC collection* was least acceptable. Nine hybrid derivatives and twelve traditional varieties were also found to be suitable for the above preparation.

Based on the over all acceptability obtained for the sixty varieties, one hybrid derivative viz., *CSRC collection* was only found unsuitable (score two or less) for fermented, (ie., *iddli, dosa,* and *appam*), steamed *(puttu)* and boiled *(kozhukkatta)* preparation. At the same time, the above variety was found suitable for cooked rice (in raw form).

4.3.8 Salient findings

Palatability characteristics of rice grains are rated to be one of the major determinants of their quality. In this study, eating quality of cooked rice was judged by ascertaining their sensory scores like appearance, colour, flavour, texture and taste.

These indicators were tested on seven preparations as already discussed.

Application of moist heat during different cooking techniques have resulted in the hydrolysis and decomposition of major nutrients like carbohydrates and proteins and this has helped to retain the characteristic flavour and taste which are highly acceptable to the traditional rice eating population especially in preparations like cooked rice (parboiled). However, application of other pre-cooking, procedures on *iddli, dosa, kozhukkatta* and *appam* had influenced the sensory qualities differently.

Moreover the procedures adopted in baking *(appam)* and steaming *(iddli* and *puttu)* had helped to bring about physical and chemical changes in rice samples where by colour, texture and appearance had improved as indicated in the scores for these preparations.

Among the seven preparations, the process of fermentation was applied on three preparations (viz., *iddli, appam* and *dosa*) and a general observation was that the rice samples lost their original colour resulting in a brownish yellow colour due to changes in protein and fat by the action of microorganisms. Further procedures adopted in these preparations had also helped to enhance the sensory qualities due to changes in starch and protein.

All these observations indicate the necessity of ascertaining the suitability of rice samples for all the seven different cooking techniques while formulating comprehensive index for measuring the quality of rice.

4.4 CLUSTER ANALYSIS (D^2 ANALYSIS)

A measure for group distance based on multiple characters was given by Mahalanobis (1928). The D^2- statistic is useful in the sense that it allowed further classification of broad morphological and physiological groups into sub groups.

Divergence analysis is performed to identify the diverse geno types for hybridization purposes. Clustering by D^2 statistic is useful in this context.

D^2- analysis was carried out for cooked rice (raw and parboiled) based on organoleptic qualities such as appearance, colour, flavour, texture and taste. In Kerala, rice as staple is mainly consumed as cooked rice. So the D^2 analysis of cooked rice (raw and parboiled) is administered to find out the divergence in varieties with respect to their organoleptic qualities.

D^2-analysis is helpful to group the divergent varieties into various clusters when measurements on a number of related characters are available on a large numbers of varieties such that the varieties within a cluster are homogenous with respect to these characters and heterogeneous between the clusters.

4.4.1 Clustering of raw rice based on organoleptic qualities. (Table 14, 15, 16 Fig. 2)

Based on D^2 values varieties of similar characters such as appearance, colour, flavour and texture were grouped together. For clustering, the varieties were arranged in increasing order of their relative distance from each other and the sixty varieties were grouped into six clusters as detailed in Table 14. Fifty one varieties were included in Cluster I, three in Cluster II, two each in Clusters III and IV and one each in clusters V and VI. The varieties which exhibited minimum divergence based on the organoleptic quality attributes got clustered together.

Table 15 presents the cluster means of five quality attributes. There occurred considerable differences in the cluster means for almost all the quality attributes. Cluster I showed high mean values for appearance (3.41) indicating that cluster I is superior to the rest of the clusters in respect of this desirable attribute. Eighteen hybrid derivatives, twenty one traditional varieties and two other improved varieties were identified under cluster I.Cluster V is superior for the characters like colour (4.00), flavour (3.80) and taste (3.50) indicating that cluster V is superior to the rest of the clusters in respect of these three quality attributes. The traditional variety Thekken was identified under cluster V. Cluster III is superior for quality attribute texture (3.75). Hybrid derivative *Karthika* and traditional variety *Chettivirippu* were identified under cluster III. Varieties under cluster II had medium score for all quality attributes. Hybrid derivatives *CSRC collection*, *Nila* and traditional variety *Teena* were identified under cluster II Varieties identified under cluster IV recorded lowest scores for appearance (1.95), colour (2.00) and texture (2.15) where as low scores for colour (2.00), flavour (2.60) and taste (2.00) were also noticed in cluster VI. Variety such as *Remya* and *Chuvannari Thavalakkannan* were identified under cluster IV where as variety *Aryankali* was identified under cluster VI.

Table 14 Clustering of raw rice varieties based on organoleptic qualities

Clusters	Varieties	Total Number
I.	Sabari, Aranmula local, Jaya, Jyothi, Kuruwa, Red Triveni, Onam, Bhadra, Asha, Pavizham, Aruna, Makom, Kanakom, Dhayna, Lakshmi, Bhagya, Sagara, Pavizhachembavu, Chitteni, Vellari, Kavunginpoothala, Veluthavattan, Kattamodan, Swarnaprabha, Swarnamodan, Bharathy, Aryan, Vadakken Chitteni, Chenkayama, Chuvannamodan, Elappapoochemban, CO-25, Jayathi, Neeraja, Navara, Thrissur local-1, Thrissur local-2, Ponnaryan, Veluthari Thavalakannan, Thekkencheera, Cheriya Aryan, Aruvakkari, Mashuri, Annapoorna, Triveni, Reshmi, Hraswa, Kutticheradi, Sinduram, Vyttila-1 and Vyttila-3	51
II	Teena, CSRC collection, Nila	3
III	Chettivirippu, Karthika	2
IV	Remya, Chuvannari Thavalakannan	2
V	Thekken	1
VI	Aryankali	1

Table 15 Cluster means of quality attributes of raw rice varieties

Quality attributes	Clusters					
	I	II	III	IV	V	VI
Appearance	3.41	2.63	3.40	1.95	3.00	2.10
Colour	3.42	2.50	3.35	2.00	4.00	2.00
Flavour	3.19	3.17	2.40	2.75	3.80	1.40
Texture	3.18	2.77	3.75	2.15	3.75	2.60
Taste	3.36	2.93	3.05	2.30	3.50	2.00

Table 16 shows the intra - inter cluster distances of raw rice varieties. Average intra - intercluster distances were worked out as follows:

Average intra-cluster distance

For the measure of intra-cluster distances, the formula used was $\frac{\Sigma D_i^2}{N}$ where ΣD_i^2 is the sum of distance between all possible combinations (N) of the varieties included in a cluster.

Average inter-cluster distance

The distance between all possible combinations of the clusters obtained were worked out. For the purpose, the sum of distance between all possible combinations of the varieties in a pair of clusters at a time was taken. The sum of D^2 values obtained divided by the product of the number of varieties in each cluster gave the inter cluster distance between the particular pair of clusters.

Minimum divergence was observed for cluster II with cluster IV, I with V, II with I, III with I, VI with III and II with V while the maximum divergence observed for III with IV, IV with V, VI ~~and~~ with I and II, I with IV and V with VI indirectly indicating the interdependence of different quality attributes of each variety with one another.

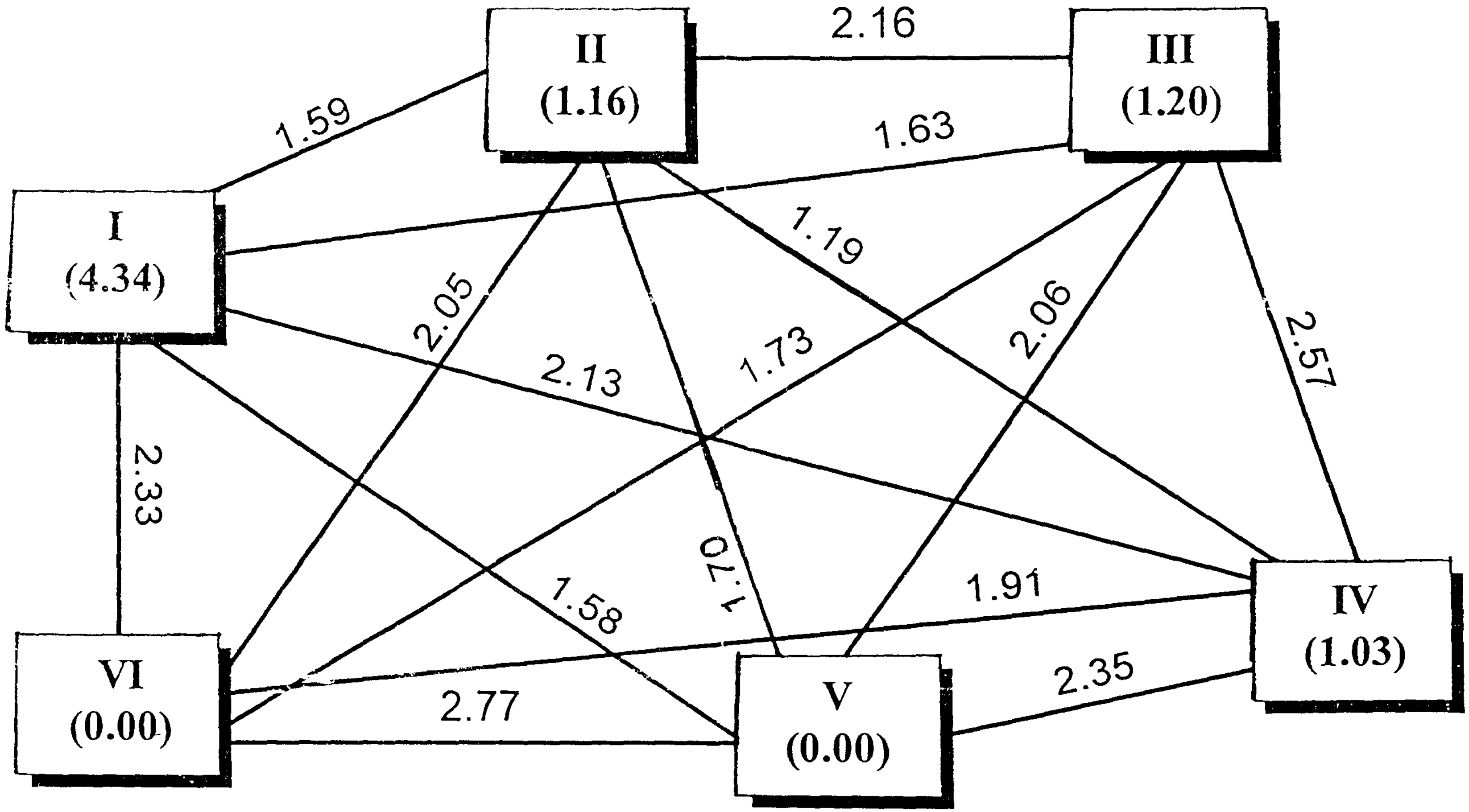
HIgh intra cluster distance within a cluster indicated high degree of variability for quality attributes within that cluster. The maximum intra cluster distance was shown by cluster I (4.34) followed by cluster III (1.20), Cluster II (1.16) and cluster IV (1.03) thereby indicating highest degree of variability in cluster I for all the quality attributes.

A cluster diagram showing all the six clusters along with their intra-inter cluster distances are furnished in Fig. 2. This diagram gives an overall picture of the distribution of the six clusters.

Table 16 Average intra - inter cluster distances of raw rice varieties

	I	II	III	IV	V	VI
I	4.34	1.59	1.63	2.13	1.58	2.33
II		1.16	2.16	1.19	1.70	2.05
III			1.20	2.57	2.06	1.73
IV				1.03	2.35	1.91
V					0.00	2.77
VI						0.00

Diagonal values are intra cluster distances.



Intra cluster distances in paranthesis

Inter cluster distances along the line

Fig. 2 CLUSTER DIAGRAM SHOWING INTRA AND INTER CLUSTER DISTANCES OF RAW RICE VARIETIES

4.4.2. Clustering of parboiled rice based on organoleptic qualities. (Table 17, 18, 19 and Fig. 3)

On the basis of the five organoleptic quality attributes such as appearance, colour, flavour, texture and taste, the sixty parboiled rice varieties were grouped through D^2 analysis and the details of which are presented in Table 17. The sixty varieties were grouped into ten clusters. Forty one varieties were included in cluster I, seven in cluster II *(Chuvannamodan, Elappapoochemban, Aruna, Remya, Vyttila-1, Pavizham* and *Vyttila-3)*, two each in cluster III *(Navara, Makom)* , cluster IV *(Sabari, Jaya), cluster V (Veluthavattan, Onam), cluster VI (Kuruwa* and *Kavunginpoothala)* and one each in cluster VII *(Vellari)*, cluster VIII *(Bharathy)*, cluster IX *(Sagara)* and cluster X *(CSRC collection)*. The varieties which exhibited minimum divergence based on the above quality attributes got clustered together.

Table 18 presents the cluster mean s of quality attributes. Considerable differences in the means were noticed in almost all the quality attributes. Cluster V showed high mean scores for appearance (4.30) and colour (4.35) whereas cluster II exhibited high scores for texture (3.73) and taste (3.71) indicating that cluster V and II were superior to the rest of the clusters in respect of their quality attributes. Cluster VII was superior for quality attribute flavour (3.80). Cluster VI recorded lowest mean scores for appearance (2.50), texture (2.40) and taste (2.05) while low scores for appearance (2.50) was also observed in clusters VIII and IX. Cluster X and Cluster VIII recorded low scores for flavour (1.50) and texture (2.40) respectively.

Table 19 shows the intra-inter cluster distances of parboiled rice varieties. The intra cluster distance was maximum in cluster I (3.47) followed by cluster II (1.24) and cluster VI (1.07) thereby indicating highest degree of variability in cluster I.

Minimum divergence was observed for cluster III with cluster VII, I with III, III with VIII, IX with VIII, I with IX, IX with III, and II with I while the maximum divergence was noticed for cluster VII with cluster X, X with V, II with X, V with IX, IV with V and V with VI indirectly indicating the interdependence of different quality attributes of each variety with one another.

Table 17 Clustering of parboiled rice varieties based on organoleptic qualities

Cluster	Varieties	Total Number
I	Chettiviripppu, Aranmula local, Jyothi, Red Triveni, Bhadra, Asha, Karthika, Kanakom, Aryankali, Dhanya, Lakshmi, Bhagya, Teena, Pavizhachembavu, Chitteni, Kattamodan, Swarnaprabha, Swarnamodan, Nila, Aryan, Vadakken Chitteni, Thekken, Chenkayama, CO-25, Jayathi, Neeraja, Thrissur local-1, Thrissur local-2, Ponnaryan, Cheriya Aryan, Aruvakkari, Mashuri, Annapoorna, Triveni, Reshmi, Hraswa, Kutticheradi, Sinduram, Veluthari Thavalakannan, Chuvannari Thavalakannan and Thekkencheera	41
II	Chuvannamodan, Elappapoochemban, Aruna, Remya, Vyttila-1, Pavizham and Vyttila - 3	7
III	Navara, Makom	2
IV	Sabari, Jaya	2
V	Veluthavattan, Onam	2
VI	Kuruwa, Karunginpoothala	2
VII	Vellari	1
VIII	Bharathy	1
IX	Sagara	1
X	CSRC collection	1

Table 19 Average intra - inter cluster distances of parboiled rice varieties

	I	II	III	IV	V	VI	VII	VIII	IX	X
I	3.47	1.34	1.21	1.46	1.73	1.68	1.36	1.37	1.30	2.28
II		1.24	1.86	1.71	1.40	2.19	1.81	2.11	1.99	2.55
III			0.39	1.52	2.21	1.57	1.09	1.24	1.30	2.40
IV				0.57	2.38	1.35	1.99	1.73	1.46	1.42
V					1.04	2.26	1.92	2.08	2.43	2.79
VI						1.07	1.75	1.38	1.75	1.63
VII							0.00	1.49	1.93	2.87
VIII								0.00	1.24	1.95
IX									0.00	2.13
X										0.00

Diagnonal values are intra cluster distances

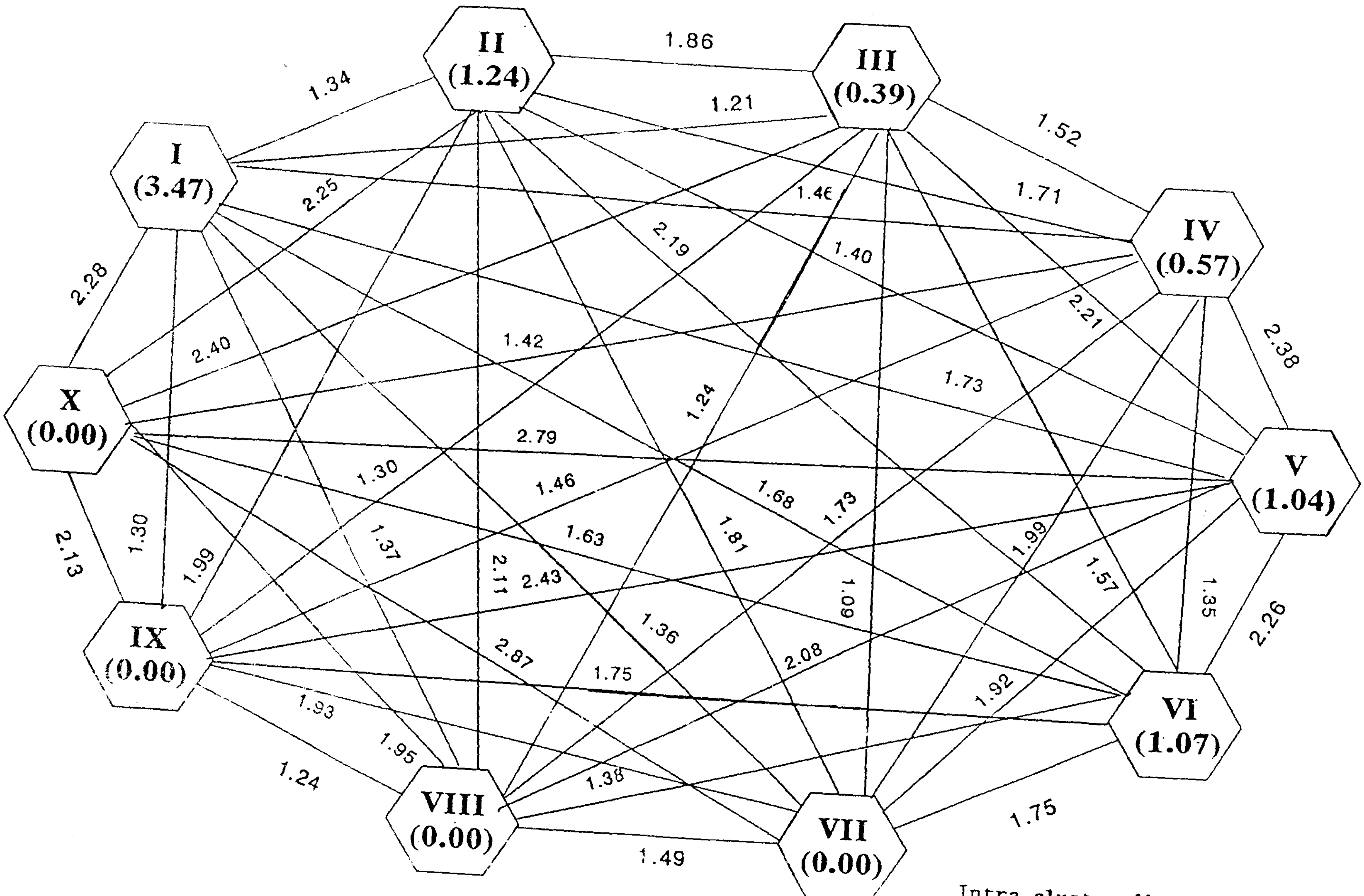
Table 18 Cluster means of quality attributes of parboiled rice varieties

Quality	Clusters									
attributes	I	II	III	IV	V	VI	VII	VIII	IX	X
Apperance	3.33	4.24	2.65	3.00	4.30	2.50	3.00	2.50	2.50	2.80
Colour	3.55	3.99	2.70	2.90	4.35	2.75	2.80	2.80	3.20	2.80
Flavour	3.52	3.79	3.40	2.80	3.60	2.60	3.80	2.60	3.10	1.50
Texture	3.23	3.73	2.95	3.50	2.85	2.40	2.50	2.40	3.50	2.90
Taste	3.30	3.71	3.15	2.70	3.45	2.05	3.10	3.00	3.50	2.10

Table 19 Average intra - inter cluster distances of parboiled rice varieties

	I	II	III	IV	V	VI	VII	VIII	IX	X
I	3.47	1.34	1.21	1.46	1.73	1.68	1.36	1.37	1.30	2.28
II		1.24	1.86	1.71	1.40	2.19	1.81	2.11	1.99	2.55
III			0.39	1.52	2.21	1.57	1.09	1.24	1.30	2.40
IV				0.57	2.38	1.35	1.99	1.73	1.46	1.42
V					1.04	2.26	1.92	2.08	2.43	2.79
VI						1.07	1.75	1.38	1.75	1.63
VII							0.00	1.49	1.93	2.87
VIII								0.00	1.24	1.95
IX									0.00	2.13
X										0.00

Diagnonal values are intra cluster distances



Intra cluster distances in paranthesis

Inter cluster distances along the line

Fig. 3 CLUSTER DIAGRAM SHOWING INTRA-INTER CLUSTER DISTANCES OF PARBOILED RICE VARIETIES

A cluster diagram showing all the ten clusters along with their intra-inter cluster distances are furnished in Fig. 3.

The results of D^2 analysis based on organoleptic qualities revealed that among sixty varieties, thirty five varieties were found to be homogeneous with respect to quality attributes such as appearance, colour, flavour, texture and taste for the preparation cooked rice either raw or parboiled rice. The results of cooked rice (raw) further revealed that cluster V, I and II were found to be superior where as cluster IV and VI recorded lowest scores for quality attributes such as appearance colour, flavour, texture and taste.

The results of cooked rice (parboiled) further revealed that considerable differences in the means were noticed in almost all the quality attributes. Varieties under cluster V showed high mean values for appearance and colour where as rice samples under cluster II exhibited high values for texture and taste indicating that the rice samples in cluster V and II were superior to the rest of the clusters in respect of their quality attributes. Varieties identified under cluster VI, VIII, IX and X recorded low mean scores for quality attributes.

4.4.3 Clustering of raw rice varieties for nutrient analysis (Table 20)

The sixty varieties of rice selected for the study were clustered on the basis of selected physical and cooking characteristic viz., length, width, thousand grain weight, head rice yield, moisture, optimum cooking time, volume expansion, water uptake, gruel loss, gelatinization temperature and viscosity. It is laborious and expensive to analyse the nutrients in all the sixty varieties both in raw and parboiled form. Hence Mahalanobis D^2 analysis was carried out to group the varieties into clusters and representative samples were taken from each cluster for nutrient analysis.

The clustering pattern of the varieties are presented in Table 20.

Table 20 Clustering of raw rice varieties based on physical and cooking characteristics

Clusters	Varieties	Total Number
I	Swarnamodan, Neeraja, Vadakken Chitteni, Vellari, Ponnaryan, Aryan, Kattamodan, Aranmula local, Veluthavattan, Navara, Sinduram, Elappapoochemban, Dhanya, Sabari, Chenkayama, Pavizham, Chuvannamodan, Lakshmi, Aruna, Kanakom and Red Triveni	21
II	Karthika, Thrissur Local-1, Pavizhachembavu, Thekkencheera, Asha, Annapoorna, Aryankali, Swarnaprabha, Chettivirippu, CO-25, Bharathy, Cheriya Aryan, Onam, Sagara, Makom, Reshmi, Thrissur local-2, Kuruwa, Teena and Triveni	20
III	Kavunginpoothala, Nila, Thekken	3
IV	Kutticheradi, Vvyttila-1, Jyothi, Chitteni, CSRC collection and Bhagya	6
V	Hraswa, Veluthari Thavalakannan and Mashuri	3
VI	Jaya. Aruvakkari	2
VII	Bhadra, Remya	2
VIII	Vyttila-3	1
IX	Chuvannari Thavalakannan	1
X	Jayathi	1

Ten clusters were formed, of which the first and second clusters included maximum varieties, 21 and 20 varieties respectively while the last three clusters consisted only single varieties viz., *Vyttila-3*, *Chuvannari Thavalakannan* and *Jayathi* respectively. The above mentioned three varieties along with two varieties from each of the seven clusters were selected for nutrient analysis. Out of the seventeen varieties selected, ten were hybrid derivatives and seven were traditional varieties. The varieties selected for nutrient analysis were(1) *Aruna* (2) *Asha* (3) *Bhadra* (4) *Bhagya* (5) *Jaya* (6) *Jayathi* (7) *Hraswa* (8) *Nila* (9) *Remya* (10) *Vyttila -3* (11) *Aruvakkari* (12) *Aryan* (13) *Chuvannari Thavalakannan* (14) *Kavunginpoothala* (15) *Kutticheradi* (16) *Thekkencheera* and (17) *Veluthari Thavalakannan.*

4.5 Nutritional Composition (Table 21, 22, 23 and Appendix 7)

Calorific value, protein, crude fibre, starch, total amylose, amylose-amylopectin ratio, ash, calcium, phosphorus and iron contents of the different varieties were determined.

4.5.1 Calorific value (Table 21)

Rice is a rich source of energy and moderate source of protein. Cereals are the main source of energy contributing seventy to eighty per cent of the daily energy need. Rice provides more calories when compared to other cereals.

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

The calorific value of seventeen rice varieties were found to vary significantly. The traditional varieties were found to be slightly richer in calories (344 kcal/100g) when compared to hybrid derivatives (327 kcal/100g). Among the varieties, the highest value of 358 kcal was noticed in the case of *Thekkencheera* (traditional variety) and the lowest of 279 kcal in *Bhadra* (hybrid derivative). Among the ten hybrid derivatives examined seven varieties were found to have less than 330 kcal/100g. While among the seven traditional varieties, all the varieties were found to have value above 331 kcal.

In the present study a significant increase in calorific value was observed in all the rice varieties, after parboiling. During parboiling, the brown outer layer (scutellum and germ) adheres to the grain and most of the nutrients in it are driven into the interior of the grain. An increase in calorific value due to parboiling was reported by Rajalakshmi (1984) and Sreedevi (1989). After parboiling traditional varieties continued to maintain a higher calorific value (357 kcal/100g) than hybrid derivatives (344 kcal/100g)

There was no varietal variation in calorific value due to parboiling.

The data when analysed statistically revealed that the interaction between varieties and processing was also found to be significant with respect to calorific value.

The increase in calorific value for individual rice varieties after parboiling were worked out. The increase in calorific value ranged between 7 and 32 kcal in hybrid derivatives while in traditional varieties it was in the range of 8 and 26 kcal.

4.5.2 Protein (Table 21)

Major determinants of calorific value of any food are carbohydrates, proteins and fats present in it. 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 (Bandyopadhyay and Roy, 1992).

As revealed by the data a wide variation in the protein content was observed among the different rice varieties. In the present study hybrid derivatives were found to have higher protein content (9.42g) when compared to traditional varieties. (7.88g). Similar findings were also reported by Mahadevappa and Shankara Gowde (1973) and Bhat and Rani (1982). The protein content in hybrid derivatives ranged from 8.67 to 10.75 g while in traditional varieties the range was between 7.01 and 8.31g. The highest protein content (10.75g) was observed in *Remya* (hybrid derivative) while the lowest value was for *Aryan* (traditional variety) (7.01g).

The variability in protein content of rice was mainly due to the environment in which it has grown. Baba (1971) had reported that the protein content varied from plant to plant.

Table 21 Calorific value, protein & crude fibre content of selected rice varieties

		Calorific Value (Kcal)		Protein (g)		Crude fibre (percent)	
Sl. No.	Variety	Raw	Parboiled	Raw	Parboiled	Raw	Parboiled
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	Aruna	334.00	361.00	9.50	9.41	0.23	0.21
2.	Asha	327.00	346.00	9.30	9.17	0.31	0.31
3.	Bhadra	279.00	304.00	9.95	9.93	0.25	0.25
4.	Bhagya	328.00	335.00	9.67	9.54	0.42	0.43
5.	Hraswa	325.00	331.00	9.01	8.90	0.43	0.42
6.	Jaya	349.00	360.00	8.67	8.11	0.29	0.29
7.	Jayathi	325.00	347.00	8.92	8.76	0.21	0.22
8.	Nila	320.00	333.00	9.67	9.47	0.31	0.31
9.	Remya	323.00	355.00	10.75	10.51	0.19	0.18
10.	Vyttila-3	355.00	363.00	8.76	8.56	0.27	0.28
	Mean	**326.50**	**343.50**	**9.42**	**9.24**	**0.29**	**0.29**
11.	Aruvakkari	348.00	356.00	7.99	7.81	0.41	0.41
12.	Aryan	345.00	353.00	7.01	6.81	0.42	0.43
13.	Chuvannari Thavalakannan	336.00	356.00	8.31	8.11	0.40	0.42
14.	Kavunginpoothala	331.00	357.00	8.15	8.00	0.21	0.22
15.	Kutticheradi	344.00	356.00	8.26	8.06	0.51	0.52
16.	Thekkencheera	358.00	366.00	7.18	6.84	0.46	0.47
17.	Veluthari Thavalakannan	347.00	356.00	8.26	7.80	0.37	0.36
	Mean	**344.14**	**357.14**	**7.88**	**7.63**	**0.39**	**0.40**
	Gross Mean	**333.78**	**349.17**	**8.79**	**8.57**	**0.33**	**0.33**
	C.D values						
	Varieties	3.014		0.031		0.013	
	Processing	1.034		0.011			
	Variety x processing	4.264		0.044			

The protein content of rice varied much with cultural practices also. High Solar radiation during grain development generally reduced protein content (Resurreccion *et al.*, 1977). Split application of nitrogen was reported to increase the protein content (Swaminathan, 1971 and Sikka *et al.*, 1993).

In this investigation parboiling and milling resulted in a decrease in the protein content. These findings are in conformity with the studies of Schroeder (1965) and Roberts (1978).

The decrease in protein content of parboiled rice might be due to decrease in total free amino acids or leaching out of non-protein nitrogen and albumin during the process of parboiling. Similar indications were observed by Schroeder (1965); Subramanian and Dakshinamoorthy (1977) and Kuzmina and Torzhinskaya (1973).

After parboiling protein content was higher in hybrid derivatives (9.24g) when compared to traditional varieties (7.63g).The highest value after parboiling was noticed in a hybrid derivative *Remya* (10.51g) while the lowest protein content was observed in traditional variety *Aryan* (6.81g).

There was a significant interaction between variety and processing. In the present study it was also observed that protein content was negatively influenced by the starch content. Higher the starch content in the grains lower was its protein content. Studies conducted by Aberg (1994) had revealed similar indications.

The decrease in protein content after parboiling was also worked out. The difference ranged between 0.02 *(Bhadra)* and 0.56g *(Jaya)*. The decrease was higher in traditional varieties when compared to hybrid derivatives. Cytochemical studies conducted by De and Rahman (1965) revealed that during parboiling, protein tended to migrate outside but was held up in the aleurone layer, which acted as a semi permeable membrane with respect to protein. The extractability of all the protein fractions decreased by an average of 45 percent following parboiling (Raghavendra Rao and Juliano, 1970). The highest decrease in protein content was noticed in hybrid derivative *Jaya* (0.56g) while the lowest decrease in protein content was noticed again in hybrid derivative *Bhadra* (0.02g).

4.5.3 Crude fibre (Table 21)

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

A significant difference in fibre content was observed among the different rice varieties. The highest value (0.51 per cent) was observed in traditional variety *Kutticheradi* while the lowest value (0.19 per cent) was for *Remya* (hybrid derivative)

In the present study, no wide variation was observed in crude fibre content of the different varieties of rice after parboiling. The variation was negligible in varieties like *Aruna, Bhagya, Jaya, Jayathi, Remya, Aryan, Chuvannari Thavalakannan and Kavunginpoothala.* The highest value of (0.52 per cent) was observed again in the traditional variety *Kutticheradi* while the lowest value (0.18 per cent) was found in hybrid derivative *Remya.* Pillaiyar (1988) has also reported that there is no varietal variation in fibre content.

Variation in fibre content among the raw and parboiled rice was also worked out. The variation ranged from 0.01 to 0.02 per cent which is not significant.

4.5.4 Starch (Table 22)

Starch is a polysaccharide formed in nature by the condensation of a large number of glucose molecules. Starch forms ninety per cent of rice by weight.

A wide variation was noticed in the starch content of the different varieties of rice. It ranged from 63.18 to 82.92 per cent. Highest starch content was recorded for the hybrid variety *Bhadra* (82.92 per cent) while the lowest starch content was observed in *Remya* (63.18 per cent), *Chuvannari Thavalakannan* (63.18 per cent) and Asha (63.18 per cent). However, the variation can be due to the difference in fibre or fat content. Hybrid derivatives were found to have high starch (72.38 per cent) when compared to traditional varieties (69.75 per cent).

Parboiling of rice grains was found to influence the starch content of the grain since during this process, starch granules are gelatinized and squeezed together making the endosperm hard and compact.

After parboiling the higher starch content was observed in hybrid derivatives (70.87 per cent) when compared to traditional varieties (68.36 per cent). Highest starch content in parboiled rice was again observed in *Bhadra* (78.04 per cent) and *Vyttila-3* (78.04 per cent). The variation in calorific value between these varieties may probably be due to the variation in fibre content. Lowest starch content was noticed in *Chuvannari Thavalakannan* (62.07 per cent) and *Remya* (62.07 per cent). Starch content of the variety *Asha* was not affected by parboiling.

4.5.5 Total amylose (Table 22)

Starch, the nutritional reservoir in rice exists in two different forms; amylose, the unbranched type of starch with glucose residues with 1-4 linkage and amylopectin, the branched form with 1-4 and 1-6 cross linkages (Aberg, 1994). According to Juliano (1970) amylose is the linear molecular component of rice starch and is the texture determinant during cooking. Rice starch is reported to be composed of 15 to 25 per cent amylose and 75 to 85 per cent amylopectin (Singh, 1993).

In the present study, the amylose content varied significantly among different varieties. However, there was no wide variation between hybrid and traditional varieties.

The same variety of rice if grown in different environment is reported to have variation in amylose groups. Similar results were reported by Paule (1977).

The highest amylose content of 25.43 per cent was noticed in *Aryan* (traditional variety) while the lowest content of 21.12 per cent in *Chuvannari Thavalakannan* (traditional variety). In the present study total amylose content ranged from 21.12 to 25.43 per cent. Similar values for amylose content in rice were reported by Gupta (1990) and Bai *et al.* (1991).

Table 22 Nature and composition of starch in selected rice varieties

Sl. No.	Variety	Starch (per cent) Raw	Starch (per cent) Parboiled	Amylose (per cent) Raw	Amylose (per cent) Parboiled	Amylose- amylopectin ratio Raw	Amylose- amylopectin ratio Parboiled
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	Aruna	71.77	70.77	24.00	20.79	0.50	0.42
2.	Asha	63.18	63.18	22.95	19.45	0.58	0.45
3.	Bhadra	82.92	78.04	22.55	20.55	0.52	0.48
4.	Bhagya	70.77	68.94	24.48	22.60	0.51	0.54
5.	Hraswa	75.81	75.33	24.81	21.61	0.50	0.50
6.	Jaya	72.71	71.71	24.68	22.83	0.52	0.51
7.	Jayathi	72.72	70.77	24.65	22.36	0.49	0.48
8.	Nila	70.30	69.83	24.57	21.66	0.54	0.51
9.	Remya	63.18	62.07	22.76	20.25	0.57	0.55
10	Vyttila-3	80.41	78.04	24.49	22.45	0.44	0.44
	Mean	**72.38**	**70.87**	**23.99**	**21.46**	**0.52**	**0.49**
11.	Aruvakkari	70.32	70.77	24.25	23.13	0.54	0.52
12.	Aryan	75.88	72.71	25.43	24.80	0.51	0.54
13.	Chuvannari - Thavalakannan	63.18	62.07	21.12	19.37	0.50	0.49
14.	Kavunginpoothala	74.88	71.77	22.15	19.59	0.42	0.43
15.	Kutticheradi	65.53	63.56	21.66	20.26	0.51	0.50
16.	Thekkencheera	64.76	63.95	24.67	22.56	0.42	0.44
17.	Veluthari Thavalakannan	73.71	73.71	24.65	22.88	0.50	0.50
	Mean	**69.75**	**68.36**	**23.42**	**21.80**	**0.49**	**0.49**
	Gross Mean	**71.29**	**69.84**	**23.76**	**21.59**	**0.50**	**0.49**
	C.D values						
	Varieties		2.092		0.045		0.016
	Processing		0.717		0.05		0.005
	Variety x processing				0.022		0.022

A significant loss in starch content was observed in all the varieties of parboiled samples except in *Aruvakkari* where increase was noted (0.45 per cent). This might be due to loss of gluten in the gruel. Negative effect of parboiling on starch content was reported earlier by Kuzmina and Torzhinskaya (1973) and Sreedevi (1989).

The difference in starch content after parboiling ranged from 0.45 to 4.88 per cent. The highest decrease in starch content was observed in hybrid derivative *Bhadra* (4.88 per cent) while the lowest decrease was noticed in traditional variety *Aruvakkari* (0.45 per cent) after parboiling.

The process of parboiling had a negative effect on the total amylose content. The amylose content decreased significantly in all the parboiled samples when compared to raw rice samples.

After parboiling, the highest value was observed in traditional variety *Aryan* (24.80 per cent) while the lowest value was observed again in traditional variety *Chuvannari Thavalakannan* (19.37 per cent).

The data when analysed statistically revealed that the interaction between variety and processing was also found to be significant with respect to total amylose content.

Based on total amylose content Juliano (1970) has classified into four categories viz.,

Waxy rice	amylose content 1 to 2 per cent
Low amylose rice	amylose content 8 to 20 per cent
Intermediate amylose rice	amylose content 21 to 25 per cent
High amylose rice	amylose content more than 25 per cent

Among the seventeen varieties studied, sixteen varieties belonged to the group "Intermediate amylose rice" and only one variety viz; *Aryan* belonged to the group "High amylose rice". None of the varieties were found to belong to 'waxy' or low amylose content category.

High amylose content results in dry and fluffy rice after cooking while glutinous or waxy rice becomes very sticky on cooking. Consumer prefers a rice grain with intermediate amylose content (Unnevehr *et al.*, 1985).

The decrease in amylose content due to parboiling was also worked out. The difference was in the range of 0.63 *(Aryan)* to 3.50 per cent *(Asha)*. Compared to traditional varieties, amylose loss from hybrid derivatives were found to be more.

4.5.6 Amylose-amylopectin ratio (Table 22)

Starch is a mixture of amylose and amylopectin. Amylopectin is the major starch constituent and is the only starch fraction of waxy (glutinous) rice (Schoch, 1967). The author also reported that the ratio of amylose to amylopectin in starch is characteristic of the plant species and is under genetic control.

The amylose-amylopectin ratio varied significantly among different rice varieties. The ratio ranged from 0.42 to 0.58.The highest ratio was found for the hybrid derivative *Asha* while the lowest value was recorded for the traditional varieties *Thekkencheera* and *Kavunginpoothala*.

Parboiling did not alter the amylose-amylopectin ratio. The highest ratio (0.55) was observed in hybrid derivative *Kemya* while the lowest ratio (0.42)was noted in traditional variety *Aruna*. The variation in the ratio among the varieties might be due to variation in the total starch and total amylose content. Similar findings were also reported by Ali and Bhattacharya (1976).

The difference in amylose - amylopectin ratio among raw and parboiled rice were also worked out and it ranged between 0.01 and 0.13. The highest difference of 0.13 was observed in hybrid derivative *Asha* while the lowest difference of 0.01 was noticed in hybrid derivatives *Jaya* and *Jayathi* and traditional varieties such as *Chuvannari Thavalakannan* and *Kutticheradi*.

4.5.7 Total ash (Table 23)

The ash content of a foodstuff is the inorganic residue remaining after the organic matter has been burnt away (Kirk and Sawyer, 1991). A significant variation in the ash content was noticed among different raw rice varieties. Compared to traditional varieties, hybrid derivatives are rich sources of ash. The highest ash content (0.84 per cent) was observed in hybrid derivative *Bhagya* while the lowest content (0.55 per cent) was noticed in traditional variety *Aryan*. Parboiling had a positive effect on ash content. Ash content of the parboiled samples were significantly higher than the raw samples.

After parboiling, the highest value was observed for the hybrid derivative *Bhagya* (0.94 per cent) while the lowest value was observed for traditional variety *Aryan* (0.61 per cent). Higher ash content in parboiled rice grains were also reported by Sreedevi (1989), Neelofer (1992) and Bandyopadhyay *et al.* (1992). The data when analysed statistically revealed that the interaction between variety and processing was also found to be significant.

The difference in ash content before and after parboiling was also worked out. The difference was in the range 0.02 and 0.15 per cent with highest difference of 0.15 per cent observed in the traditional variety *Veluthari Thavalakannan* and the lowest difference noticed in hybrid derivative *Aruna* (0.02 per cent).

4.5.8 Phosphorus (Table 23)

A significant variation was found among different varieties of raw rice in phosphorus content. The highest phosphorus content observed in hybrid variety *Jayathi* (155.50mg/100g) while the lowest value was for the traditional variety *Kavunginpoothala* (116mg/100g).

Parboiling is found to increase the phosphorus content significantly in all the varieties of rice grains, because of the diffusion of minerals from the outer layers into the endosperm and spreading and redistribution among the various parts during soaking and steaming of the grain. The highest value of 182 mg/100g was observed for the hybrid derivatives *Jayathi* and the lowest phosphorus content of 129mg/100g was found in the traditional variety *Kavunginpoothala*. Studies conducted by Pillaiyar (1988) and Bandyopadhyay *et al.* (1992) had also indicated the influence of parboiling on phosphorus content on similar lines. The difference in phosphorus content between raw and parboiled rice were worked out. The difference was in the range of 2.25 *(Asha)* and 49.00 mg/100g *(Kutticheradi)*.

The data when analysed statistically revealed that the interaction between variety and processing methods were also found to be significant with respect to phosphorus content.

4.5.9 Calcium (Table 23)

A significant difference in the calcium content was observed among the different rice varieties. The highest calcium content for raw rice was noticed in hybrid derivative *Vyttila-3* (11.25 mg/100g) while the lowest calcium content was recorded for hybrid derivative *Bhadra* (9.80 mg/100g).The high yielding rice varieties of Kerala Agricultural University were reported to contain calcium ranging from 8.2 - 10.9 mg/100g (Sreedevi, 1989).

Parboiling process positively influences the calcium content of the rice varieties. Lower calcium content in raw rice when compared to parboiled rice may be due to removal of the outer layers which constitute approximately five per cent of the whole kernel by weight. A comparison among different rice samples gave significant variation in their calcium content. The retention of calcium was higher due to parboiling in *Vyttila-3* (11.81 mg/100g) while the retention was lower in *Bhadra* (10.24 mg/100g) when compared to other varieties. During parboiling calcium migrated deep into the grain resulting in a greater retention of the nutrient in the milled parboiled grain. The influence of parboiling in retaining calcium was also reported by Ocker *et al.* (1976).

Calcium retention due to parboiling was also worked out in individual rice samples. The highest increase was observed in the variety *Remya* (0.61mg/100g) while the lowest increase was recorded for the variety *Jayathi* (0.24 mg/100g)

The data when analysed statistically revealed that the interaction between variety and processing method was also found to be significant with respect to calcium content.

Table 23 Mineral profile of selected rice varieties

Sl. No.	Variety	Total ash (per cent) Raw	Total ash (per cent) Parboiled	Phosphorus (mg./100 g.) Raw	Phosphorus (mg./100 g.) Parboiled	Calcium (mg./100 g.) Raw	Calcium (mg./100 g.) Parboiled	Iron (mg/100 g.) Raw	Iron (mg/100 g.) Parboiled
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	Aruna	0.68	0.70	125.45	141.00	10.09	10.44	3.31	3.42
2.	Asha	0.72	0.82	127.75	130.00	10.04	10.59	3.16	3.40
3.	Bhadra	0.74	0.84	124.25	135.50	9.80	10.24	3.37	3.44
4.	Bhagya	0.84	0.94	130.00	145.00	10.37	10.88	3.24	3.41
5.	Hrswa	0.56	0.67	136.75	153.00	10.24	10.68	3.42	3.49
6.	Jaya	0.67	0.75	131.00	167.75	10.63	11.04	2.95	3.22
7.	Jayathi	0.67	0.75	155.50	182.00	9.85	10.61	2.80	3.31
8.	Nila	0.69	0.75	141.75	162.83	10.79	11.44	2.65	3.16
9.	Remya	0.71	0.81	143.75	163.00	10.23	10.84	3.33	3.43
10.	Vyttila-3	0.66	0.76	152.00	168.00	11.25	11.81	3.28	3.37
	Mean	**0.69**	**0.78**	**136.82**	**154.81**	**10.33**	**10.86**	**3.15**	**3.37**
11.	Aruvakkari	0.61	0.72	121.50	145.50	10.44	10.85	2.78	3.19
12.	Aryan	0.55	0.61	123.00	150.50	11.03	11.56	2.52	2.80
13.	Chuvannari Thavalakannan	0.56	0.68	126.50	150.00	10.75	11.18	2.84	3.03
14.	Kavunginpoothala	0.63	0.73	116.00	129.00	11.11	11.66	3.12	3.19
15.	Kutticheradi	0.59	0.67	131.00	180.00	10.63	11.03	2.96	3.02
16.	Thenkkencheera	0.59	0.67	123.25	155.25	10.24	10.64	2.53	2.89
17.	Veluthari Thavalakannan	0.61	0.75	151.00	165.50	10.73	11.27	2.80	3.22
	Mean	**0.59**	**0.69**	**127.46**	**153.68**	**10.70**	**11.17**	**2.79**	**3.04**
	Gross Mean	**0.65**	**0.74**	**132.97**	**154.34**	**10.48**	**10.99**	**3.00**	**3.23**
	C.D values								
	varieties	0.026		1.800		0.098		0.127	
	Processing	0.009		0.618		0.034		0.043	
	Variety x Processing	0.037		2.546		0.139		0.179	

4.5.10 Iron (Table 23)

A significant difference in the iron content was observed among different varieties of rice.

A comparison of raw samples revealed that iron content ranged from 2.52 to 3.42 mg/100g. Hybrid derivatives are richer in iron than traditional varieties. The highest value of 3.42 mg/100g was found in the variety *Hraswa* (3.42mg/100g) and the lowest value of 2.52mg/100g was found in traditional variety *Aryan*. The mineral elements migrated deep into the grain during parboiling, resulting in a greater retention of this nutrient in milled parboiled grain.

Parboiling of rice samples had influenced the iron content significantly. Iron was found to be retained more in parboiled rice samples when compared to raw rice samples. This confirms the results of Doesthale et al. (1979) and Damir (1985).

The highest iron content after parboiling was observed for the hybrid derivative *Hraswa* (3.49 mg/100g) while the lowest content was reported in a traditional variety called *Aryan* (2.80 mg/100g). The interaction between varieties and processing method was also found to be significant.

Among the various indicators studied under nutritional composition, traditional varieties of rice were found to have higher values for calorific value, starch and crude fibre. The protein, amylose and mineral contents were found to be higher in hybrid derivatives when compared to traditional varieties. Parboiling had a positive influence on the calorific value, ash and minerals and a negative effect on starch, protein and amylose content .

The quality of cooked rice depend largely on the proportion of amylose and amylopectin, the two starch fraction of rice endosperm. In the present study varieties such as *Bhagya, Hraswa, Jaya, Jayathi, Nila, Vyttila-3, Aryan, Thekkencheera and Veluthari Thavalakannan* were found to have amylose around 25 per cent and rice varieties with around 25 per cent amylose content are preferred because of their volume expansion and high degree of flakiness on cooking.

4.6 DEVELOPMENT OF QUALITY INDICES (TABLE 24, 25, 26 and 27)

Discriminant function of Fisher (1936) is used to define the merit of rice varieties on the basis of physical, cooking, organoleptic and nutritional composition.

4.6.1. Index based on physical, cooking and organoleptic qualities (Table 24 and figure 4, 5, 6)

Physical dimensions viz., length, breadth or width, thickness and shape of the kernels determines the varietal differentiations in rice according to Bandyopadhyay and Roy (1992) in developing new varieties for commercial production. The index score varied from 94.24 to 204.38 in raw rice and 96.98 to 206.58 in parboiled rice. The highest rank was secured by *Vyttila-3* (204.38) followed by *Chuvannari Thavalakannan* (197.27) and *Hraswa* (186.13) while lowest rank was scored by *Kavunginpoothala* (94.24) followed by *Thekken* (100.7 4) in raw rice.

More or less the same trend was noticed in parboiled rice also. Vyttila-3 scored an index value of 206.58 followed by *Chuvannari Thavalakannan* (199.39) and *Hraswa* (188.62) and the lowest rank was assigned to *Kavunginpoothala* (96.98) followed by *Thekken* (103.07).

Cooking characteristics play a vital role in determining the quality of rice. According to Juliano (1985) there was a definite relationship between the physico-chemical characters and cooking qualities of rice varieties. Based on the cooking qualities, the highest rank was obtained for *CSRC collection* (290.91) with a range of variation in the index values 210.96 to 290.91 in raw rice while the lowest rank was scored by *Ponnaryan*. *Vyttila-3* (333.93) and *CSRC collection* (333.34) scored the top most ranks and *Lowest ranks by Elappapoochemban* (250.14) and *Neeraja* (252.85) in parboiled rice. This study is in agreement with the observations reported by Geervani and George (1971) that hybrid derivatives were found to have better index score. Amylose content in rice was considered as one of the important factors in rice. It was considered important in describing and predicting the cooking and eating qualities of rice and water absorption and volume expansion during cooking. (Neelofer, 1992).

Table 24 Quality index for rice varieties, based on physical, cooking and organoleptic characteristics

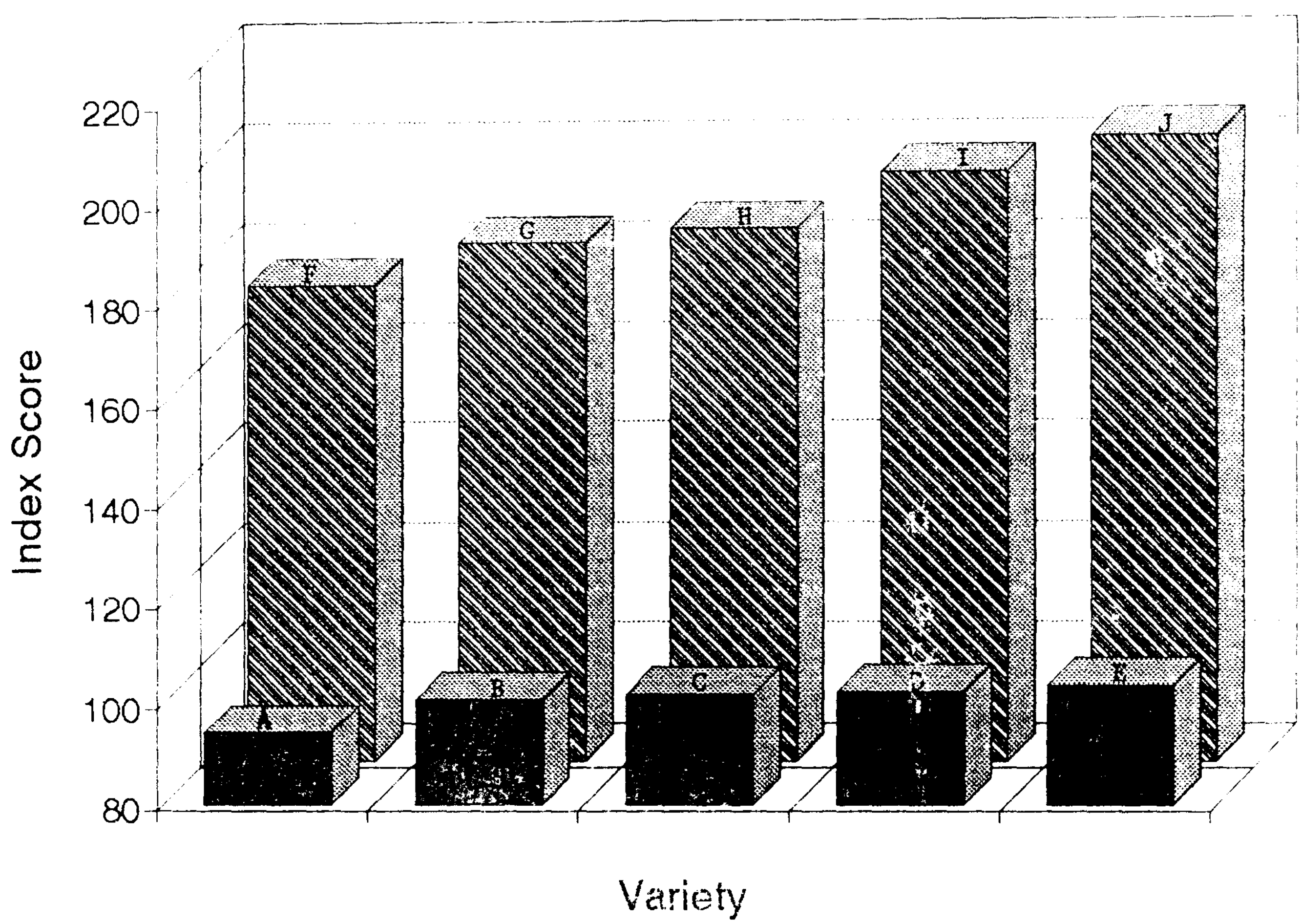
		Index scores				
		Physical characteristics		Cooking characteristics		Organoleptic Qualities
Sl.No.	Variety	(Raw)	(Parboiled)	(Raw)	(Parboiled)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Vyttila - 3	204.38 (01)	206.58 (01)	281.72 (03)	333.93 (01)	164.37 (04)
2.	Chuvannari Thavalakannan	197.27 (02)	199.39 (02)	241.99 (43)	278.15 (43)	140.36 (35)
3.	Hraswa	186.13 (03)	188.62 (03)	266.27 (13)	281.62 (40)	143.80 (33)
4.	Veluthari Thavalakannan	183.27 (04)	185.29 (04)	252.39 (31)	281.50 (41)	154.64 (19)
5.	Kattamodan	174.93 (05)	177.07 (05)	235.74 (51)	290.06 (30)	166.93 (03)
6.	Vadakken Chitteni	163.25 (06)	165.53 (06)	237.76 (49)	284.05 (37)	148.75 (26)
7.	Aryan	163.20 (07)	165.46 (07)	238.51 (48)	265.61 (53)	160.30 (10)
8.	Ponnaryan	161.08 (08)	163.27 (08)	210.96 (60)	264.09 (55)	153.26 (21)
9.	Mashuri	159.65 (09)	162.04 (09)	234.70 (53)	259.44 (57)	152.03 (23)
10	Remya	157.93 (10)	160.55 (10)	271.58 (08)	293.05 (28)	120.61 (53)
11.	Vellari	156.84 (11)	158.92 (11)	235.12 (52)	291.88 (29)	163.17 (05)
12.	Sabari	155.85 (12)	158.46 (12)	262.87 (18)	296.58 (25)	119.97 (55)
13.	Neeraja	152.01 (13)	154.50 (13)	226.05 (58)	252.85 (59)	158.82 (14)
14.	Swarnamodan	151.36 (14)	153.65 (14)	233.85 (55)	266.89 (52)	161.20 (09)
15.	Onam	147.80 (15)	150.16 (15)	281.20 (04)	331.05 (04)	117.60 (57)
16.	Makom	147.18 (16)	149.66 (16)	259.37 (25)	297.31 (24)	126.95 (51)
17.	Bhadra	147.06 (17)	149.01 (17)	267.72 (12)	332.95 (03)	129.63 (49)
18.	Chenkayama	146.89 (18)	148.90 (18)	267.73 (11)	308.57 (15)	162.71 (07)
19.	Dhanya	146.28 (19)	148.28 (19)	245.62 (39)	276.01 (45)	136.79 (40)
20	Chuvannamodan	146.17 (20)	148.08 (20)	255.41 (27)	277.93 (44)	157.49 (16)
21.	Veluthavattan	145.57 (21)	147.42 (21)	249.33 (34)	282.68 (39)	169.59 (01)
22.	Jaya	144.58 (22)	146.55 (22)	234.43 (54)	299.89 (20)	133.02 (45)

1	2	3	4	5	6	7
23.	Asha	144.06 (23)	146.27 (23)	265.38 (15)	313.71 (09)	130.03 (47)
24.	Chettivirippu	143.68 (24)	145.99 (25)	260.94 (20)	309.23 (14)	114.96 (59)
25.	Aranmula local	143.67 (25)	146.25 (24)	240.86 (44)	311.86 (11)	130.31 (46)
26.	Kutticheradi	143.38 (26)	145.72 (26)	272.46 (06)	307.22 (16)	137.69 (38)
27.	Pavizham	142.82 (27)	145.13 (27)	250.89 (33)	296.05 (26)	148.22 (27)
28.	Elappapoochemban	142.36 (28)	144.56 (28)	240.45 (45)	250.14 (60)	156.39 (17)
29.	Aruna	142.27 (29)	144.49 (29)	265.29 (16)	287.06 (34)	153.61 (20)
30.	Navara	141.63 (30)	144.09 (30)	251.43 (32)	286.33 (35)	134.23 (43)
31.	Kanakom	141.50 (31)	143.85 (31)	267.76 (10)	274.13 (47)	136.99 (39)
32.	Vyttila -1	141.47 (32)	143.70 (32)	277.11 (05)	315.11 (07)	168.31 (02)
33.	Chitteni	140.94 (33)	143.04 (34)	268.99 (09)	294.64 (27)	160.06 (11)
34.	Sinduram	140.80 (34)	143.03 (35)	249.09 (35)	312.47 (10)	138.88 (37)
35.	Aruvakkari	140.65 (35)	143.09 (33)	227.67 (57)	256.10 (58)	143.82 (32)
36.	Jyothi	138.02 (36)	139.82 (36)	260.51 (22)	289.67 (31)	125.82 (52)
37.	Lakshmi	136.88 (37)	138.87 (37)	229.89 (56)	282.97 (38)	135.65 (41)
38.	Sagara	136.44 (38)	138.57 (38)	259.56 (24)	269.52 (49)	143.42 (34)
39.	Thekkencheera	135.97 (39)	138.45 (39)	247.53 (36)	264.42 (54)	145.37 (30)
40.	Karthika	133.04 (40)	134.81 (40)	266.12 (14)	313.74 (08)	143.85 (31)
41.	Red Triveni	131.95 (41)	134.10 (41)	261.03 (19)	310.57 (13)	115.89 (58)
42.	Cheriya Aryan	131.36 (42)	133.47 (42)	238.60 (47)	267.04 (51)	147.94 (28)
43.	Bhagya	129.80 (43)	132.45 (43)	287.25 (02)	287.76 (32)	133.10 (44)
44.	Aryankali	129.41 (44)	131.53 (44)	260.39 (23)	301.07 (19)	120.17 (54)
45.	Swarnaprabha	127.03 (45)	129.41 (45)	255.20 (28)	271.95 (48)	159.12 (12)
46.	CSRC collection	121.61 (46)	124.25 (46)	290.91 (01)	333.34 (02)	79.89 (60)
47.	Thrissur local -1	121.52 (47)	123.76 (47)	271.75 (07)	284.52 (36)	156.23 (18)
48.	Reshmi	120.47 (48)	121.99 (48)	239.66 (46)	311.23 (12)	158.84 (13)

1	2	3	4	5	6	7
49.	Pavizhachembavu	119.53 (49)	121.91 (49)	254.70 (30)	321.72 (06)	129.32 (50)
50.	Annapoorna	117.29 (50)	118.41 (51)	237.56 (50)	301.27 (18)	153.23 (22)
51.	Kuruwa	117.02 (51)	118.79 (50)	254.91 (29)	298.53 (21)	118.21 (56)
52.	Bharathy	115.11 (52)	116.49 (53)	264.58 (17)	303.67 (17)	139.55 (36)
53.	Teena	114.13 (53)	117.28 (52)	246.48 (38)	297.59 (23)	129.70 (48)
54.	Thrissur local -2	106.52 (54)	108.49 (54)	247.12 (37)	267.66 (50)	135.22 (42)
55.	Nila	106.45 (55)	108.28 (55)	243.78 (40)	262.43 (56)	145.42 (29)
56.	CO -25	103.52 (56)	105.84 (56)	242.09 (42)	274.89 (46)	163.12 (06)
57.	Jayathi	102.29 (57)	103.99 (57)	213.71 (59)	279.06 (42)	158.41 (15)
58.	Triveni	101.54 (58)	103.58 (58)	242.37 (41)	329.99 (05)	151.82 (24)
59.	Thekken	100.74 (59)	103.07 (59)	260.91 (21)	287.19 (33)	149.93 (25)
60.	Kavunginpoothala	94.24 (60)	96.98 (60)	255.75 (26)	297.68 (22)	161.99 (08)

(Numbers in paranthesis indicate rank order.)

Fig4 Index for physical characteristics of selected rice varieties

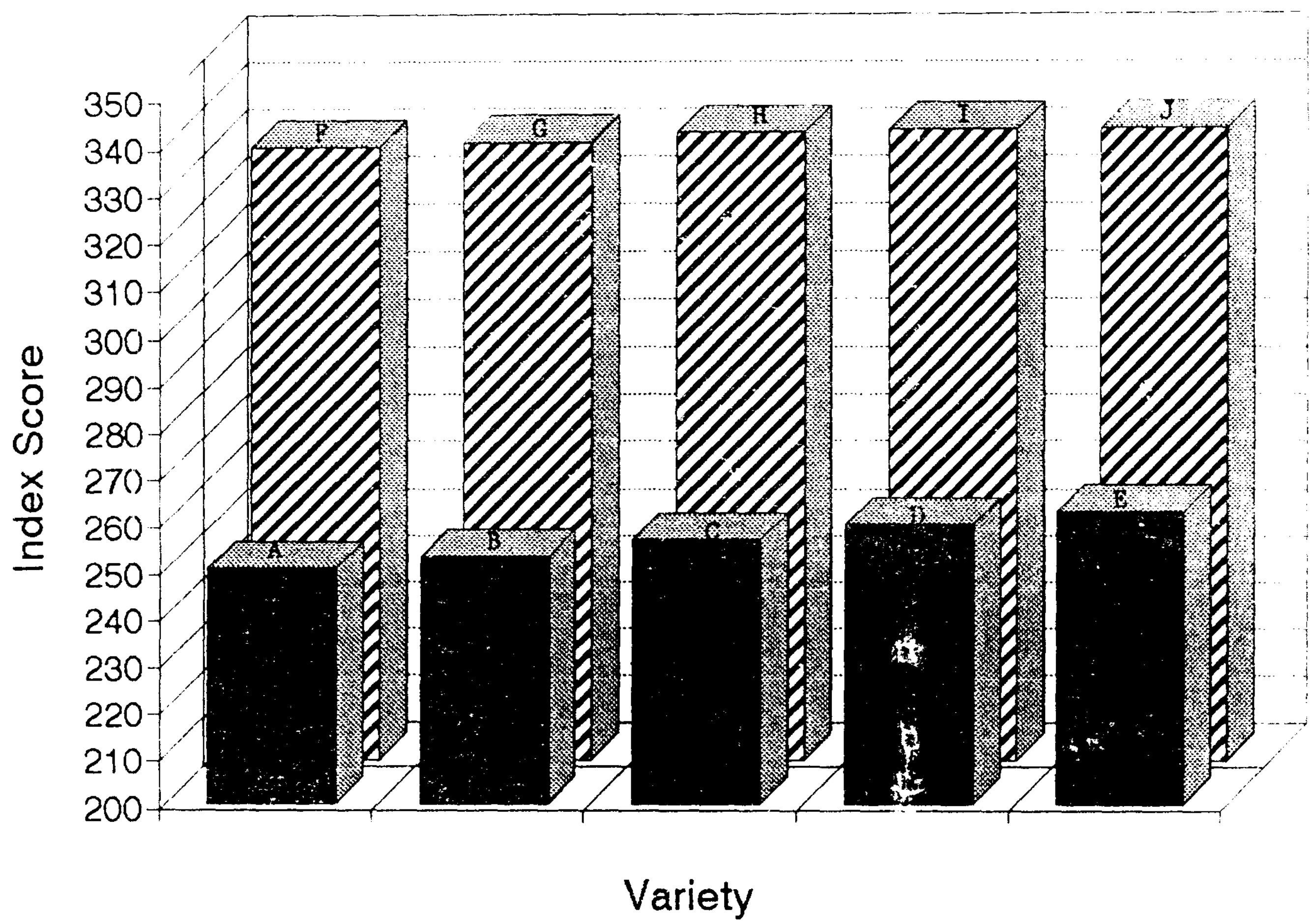


A: Kavunginpoothala B: Thekken C: Triveni D: Jayathi

E: CO-25 F: Kattamodan G: Veluthari Thavalakkannan H: Hraswa

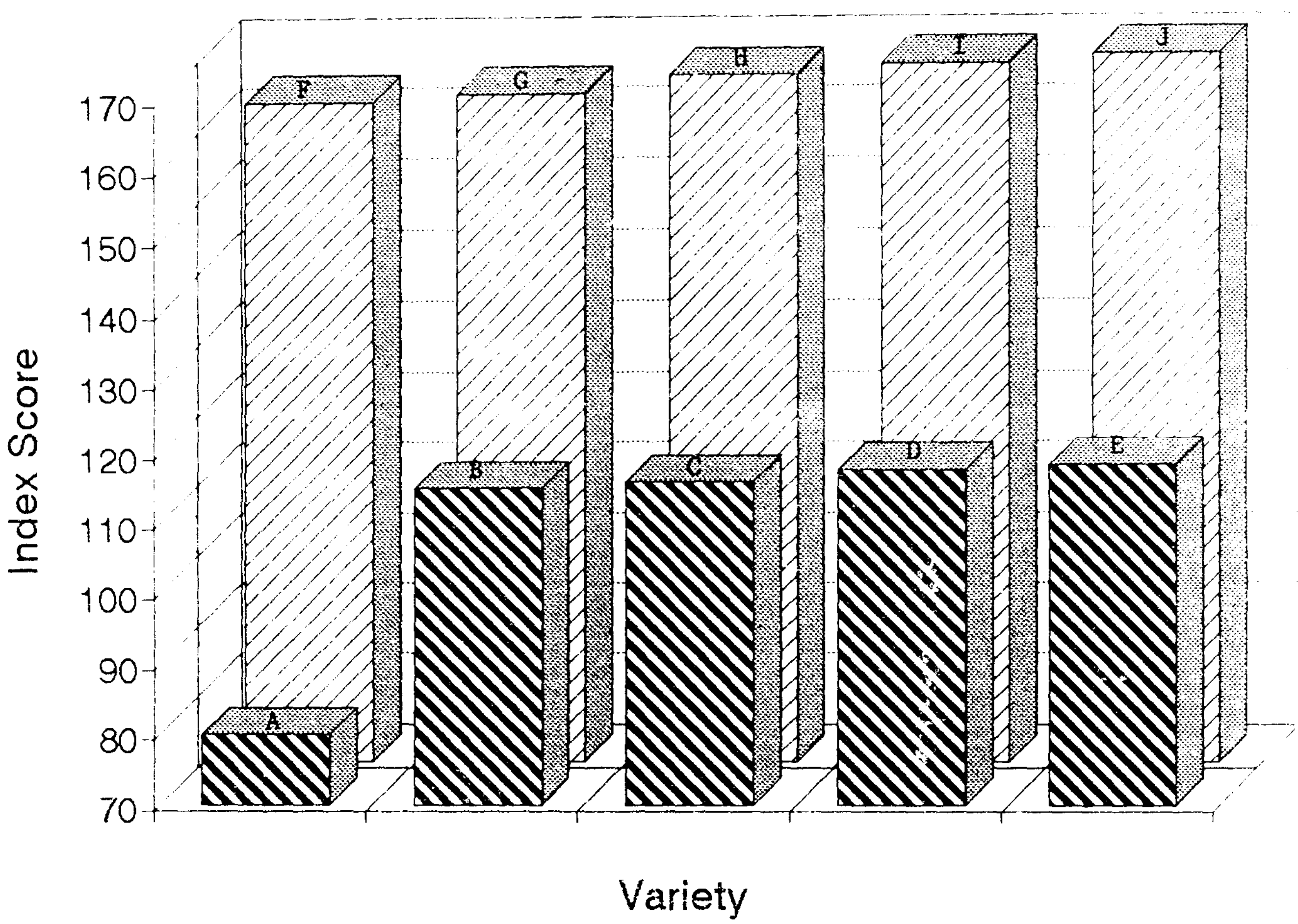
I: Chuvannari Thavalakkannan J: Vyttila-3

Fig.5 Index for cooking characteristics of selected rice varieties



A:	Elappapoochemban	B:	Neeraja	C:	Aruvakkari	D:	Mashuri
E:	Nila	F:	Triveni	G:	Onam	H:	Bhadra
I:	CSRC Collection	J:	Vyttila-3				

Fig.6 Index for organoleptic qualities of selected rice varieties



A:	CSRC Collection	B:	Chetti Virippu	C:	Red Triveni
D:	Onam	E:	Kuruwa	F:	Vellari
G:	Vyttila-3	H:	Kattamodan	I:	Vyttila-1
J:	Veluthavattan				

Raghavendra Rao et al (1970) had reported that proportion between amylose and amylopectin contents determine the cooking quality of rice. As such *CSRC collection* in raw rice and *Vyttila-3* and *CSRC collection* in parboiled rice were found to be the top most varieties based on their cooking qualities. This may be attributed to the comparatively higher content of amylose/amylopectin present in these varieties.

The organoleptic characteristics (colour, appearance, cohesiveness, tenderness and flavour) contribute an important factor in grading the quality of rice. While considering the index scores of organoleptic characteristics *Veluthavattan* scored the highest rank (169.59) followed by *Vyttila-1* (168.31) and the lowest score was secured by *CSRC collection* (79.89) and *Chettivirippu* (114.96). A perusal of the table also revealed that majority of the varieties in the 1 to 10 ranks were traditional/local varieties having the superior organoleptic qualities of the staple food.

4.6.2 Acceptability index for various rice based preparations (Table 25)

In the case of cooked rice using raw rice, the hybrid derivative Vyttila-3 scored the 1st rank with an index score of 487.99 followed by Hraswa with an index score of 453.39. The lowest rank was secured by *Jayathi* with an index score of 319.65 while in the case of parboiled rice the ranking was in the order of *Vyttila-3* (519.77) followed by *Bhadra* (463.86). Hybrid derivative *Nila* scored the lowest rank (351.71).

Hybrid derivatives *Vyttila-3* (540.43) and *Bhadra* (482.89) scored the first two ranks indicating the suitability for the preparation *iddli*. The hybrid derivative *Nila* again (371.75) was found to be not at all acceptable for the above preparation.

As in the case of cooked rice (raw), in the case of preparation *dosa* also the same trend was noticed showing that *Vyttila-3* secured the highest rank with an index score of 469.84 followed by *Hraswa* (436.35). In this case also the lowest rank goes to hybrid derivative *Jayathi* (301.64).

For the preparation *puttu*, the hybrid derivatives *Vyttila-3* and *Hraswa* were found to be the superior ones with an index score of 457.26 and 423.82 respectively. The hybrid derivative *Jayathi* secured the lowest rank with an index score of 289.07.

Table 25 Acceptability index based on physical, cooking and organoleptic characteristics for various rice based preparations.

Sl. No.	Variety	Index score: Cooked rice (Raw)	Cooked rice (Parboiled)	Iddli	Dosa	Puttu	Kozhukkatta	Appam
1	2	3	4	5	6	7	8	9
1.	Vyttila-3	487.99 (01)	519.77 (01)	540.43 (01)	469.84 (01)	457.26 (01)	449.38 (1)	420.77 (01)
2.	Hraswa	453.39 (02)	451.90 (05)	470.34 (06)	436.35 (02)	423.82 (02)	417.34 (2)	437.34 (02)
3.	Chuvannari - Thavalakannan	439.20 (03)	457.80 (04)	479.72 (04)	425.03 (03)	411.90 (03)	405.38 (03)	426.07 (03)
4.	Veluthari Thavalakannan	435.83 (04)	446.75 (07)	469.67 (07)	419.29 (04)	406.52 (04)	398.66 (04)	419.68 (04)
5.	Onam	431.19 (05)	462.72 (03)	480.39 (03)	413.03 (05)	400.23 (05)	394.20 (06)	416.82 (05)
6.	Remya	427.02 (06)	433.99 (15)	452.53 (16)	411.85 (06)	400.05 (06)	394.37 (05)	415.93 (06)
7.	Vyttila-1	420.97 (07)	440.64 (09)	461.30 (08)	402.71 (07)	389.59 (07)	380.77 (08)	403.53 (08)
8.	Sabari	420.95 (08)	434.66 (14)	453.90 (13)	402.31 (08)	389.35 (08)	383.15 (07)	405.32 (07)
9.	Bhagya	417.21 (09)	399.61 (40)	420.62 (43)	399.02 (12)	386.93 (10)	379.78 (10)	401.69 (10)
10.	Chenkayama	417.02 (10)	438.32 (10)	459.60 (10)	400.05 (10)	385.66 (12)	378.14 (13)	401.39 (11)
11.	Bhadra	416.85 (11)	463.86 (02)	482.89 (02)	400.30 (09)	387.52 (09)	380.54 (09)	402.69 (09)
12.	Kutticheradi	414.85 (12)	431.96 (17)	451.39 (19)	399.29 (11)	385.72 (11)	378.40 (12)	399.77 (12)
13.	Chitteni	414.10 (13)	418.17 (26)	441.57 (26)	396.68 (14)	382.90 (16)	374.81 (16)	398.68 (13)
14.	Kattamodan	413.89 (14)	447.96 (06)	470.82 (05)	396.94 (13)	383.54 (13)	377.45 (14)	398.31 (15)
15.	CSRC collection	413.83 (15)	435.25 (12)	453.18 (15)	395.10 (16)	383.20 (15)	379.61 (11)	395.86 (17)
16.	Kanakom	413.26 (16)	399.51 (41)	416.80 (44)	392.71 (18)	381.33 (17)	373.52 (18)	396.26 (16)
17.	Asha	412.99 (17)	442.10 (08)	460.69 (09)	395.61 (15)	383.35 (14)	377.09 (15)	398.33 (14)
18.	Aruna	410.40 (18)	412.62 (31)	435.78 (29)	394.08 (17)	379.65 (18)	374.27 (17)	394.54 (18)
19.	Makom	407.14 (19)	428.04 (21)	446.17 (22)	389.09 (19)	377.45 (19)	370.34 (19)	393.60 (19)
20.	Chettivirippu	406.58 (20)	434.77 (13)	452.01 (17)	398.06 (20)	375.86 (20)	370.08 (20)	391.52 (20)
21.	Vadakken Chitteni	404.97 (21)	430.39 (19)	450.99 (20)	387.04 (22)	374.45 (22)	368.42 (21)	387.98 (23)

1	2	3	4	5	6	7	8	9
22.	Chuvannamodan	404.84 (22)	408.01 (34)	429.07 (35)	387.21 (21)	374.63 (21)	368.15 (22)	388.54 (21)
23.	Aryan	404.30 (23)	412.34 (32)	433.76 (31)	386.96 (23)	373.61 (23)	366.94 (23)	388.24 (22)
24.	Jyothi	402.64 (24)	406.79 (36)	424.57 (37)	382.76 (25)	369.52 (25)	362.29 (25)	385.52 (24)
25.	Karthika	401.20 (25)	429.94 (20)	451.51 (18)	382.80 (24)	370.26 (24)	363.95 (24)	385.39 (25)
26.	Sagara	399.97 (26)	389.14 (47)	410.47 (47)	380.90 (26)	368.21 (26)	361.49 (26)	384.05 (26)
27.	Veluthavattan	398.86 (27)	412.69 (30)	433.71 (32)	380.60 (27)	366.45 (28)	358.69 (28)	382.26 (27)
28.	Mashuri	397.69 (28)	399.41 (44)	421.90 (39)	379.12 (28)	366.72 (27)	359.34 (27)	381.59 (28)
29.	Vellari	397.01 (29)	431.53 (18)	454.24 (12)	378.79 (29)	364.47 (31)	356.73 (33)	380.86 (30)
30.	Red Triveni	396.49 (30)	427.01 (22)	443.75 (25)	377.49 (30)	364.69 (29)	357.55 (30)	381.53 (29)
31.	Thrissur local - 1	396.22 (31)	387.65 (48)	408.73 (48)	377.39 (32)	363.99 (33)	356.77 (32)	379.11 (32)
32.	Pavizham	394.36 (32)	423.96 (24)	445.16 (23)	377.48 (31)	364.29 (32)	356.99 (31)	379.02 (33)
33.	Dhanya	394.30 (33)	405.90 (37)	426.39 (36)	377.07 (33)	362.87 (34)	356.40 (34)	377.57 (34)
34.	Navara	393.70 (34)	408.33 (33)	429.54 (34)	375.67 (34)	364.68 (30)	357.79 (29)	379.29 (31)
35.	Sinduram	392.27 (35)	433.94 (16)	453.89 (14)	375.59 (35)	362.42 (35)	355.41 (36)	376.84 (35)
36.	Swarnamodan	388.03 (36)	402.90 (38)	424.33 (38)	371.47 (37)	358.33 (37)	351.74 (37)	373.66 (37)
37.	Aranmula local	387.70 (37)	435.68 (11)	456.43 (11)	369.28 (38)	355.76 (39)	350.04 (38)	372.32 (38)
38.	Aryankali	387.31 (38)	413.59 (29)	434.33 (30)	373.70 (36)	361.39 (36)	355.61 (35)	374.21 (36)
39.	Swarnaprabha	386.41 (39)	381.74 (52)	404.38 (51)	368.79 (40)	354.47 (41)	346.36 (41)	370.10 (39)
40.	Elappapoochemban	384.76 (40)	376.21 (54)	395.60 (55)	368.87 (39)	355.17 (40)	347.93 (40)	369.68 (40)
41.	Thekkencheera	384.11 (41)	384.16 (50)	406.02 (50)	368.24 (41)	355.95 (38)	348.33 (39)	368.73 (41)
42.	Bharathy	381.07 (42)	399.45 (43)	421.35 (40)	362.96 (42)	350.43 (42)	343.06 (42)	364.65 (42)
43.	Neeraja	379.89 (43)	386.29 (49)	407.82 (49)	362.95 (43)	349.85 (43)	342.65 (44)	364.24 (43)
44.	Jaya	379.29 (44)	426.28 (23)	447.44 (21)	362.91 (44)	348.75 (44)	343.02 (43)	363.82 (44)
45.	Kuruwa	375.39 (45)	396.07 (45)	416.01 (45)	355.87 (48)	342.71 (48)	336.14 (48)	359.42 (46)
46.	Pavizhachembavu	374.89 (46)	423.81 (25)	444.22 (24)	357.37 (46)	344.99 (45)	339.27 (45)	359.64 (45)
47.	Ponnaryan	374.61 (47)	407.92 (35)	431.06 (33)	358.30 (45)	344.62 (46)	337.40 (46)	359.24 (47)

1	2	3	4	5	6	7	8	9
48.	Cheriya Aryan	372.04 (48)	382.80 (51)	404.28 (52)	356.43 (47)	343.90 (47)	336.33 (47)	357.46 (48)
49.	Aruvakkari	371.51 (49)	380.48 (53)	400.09 (53)	353.99 (49)	341.79 (49)	334.56 (49)	356.84 (49)
50.	Lakshmi	369.12 (50)	402.54 (39)	421.09 (41)	351.35 (50)	340.22 (50)	333.66 (50)	354.30 (50)
51.	Reshmi	363.42 (51)	414.15 (28)	437.01 (27)	346.74 (51)	332.12 (52)	325.47 (51)	348.31 (51)
52.	Thekken	363.09 (52)	371.09 (56)	393.29 (56)	345.09 (52)	332.58 (51)	325.20 (52)	346.69 (52)
53.	Teena	359.11 (53)	394.60 (46)	414.68 (46)	343.65 (53)	331.28 (53)	324.41 (53)	344.62 (53)
54.	Annapoorna	358.62 (54)	399.48 (42)	420.90 (42)	341.07 (54)	328.55 (54)	321.51 (54)	344.52 (54)
55.	Thrissur local-2	355.47 (55)	354.70 (59)	375.38 (59)	337.30 (55)	325.94 (55)	318.77 (55)	340.43 (55)
56.	Nila	351.86 (56)	351.71 (60)	371.75 (60)	336.36 (56)	324.16 (56)	317.45 (56)	337.41 (57)
57.	Kavunginpoothala	350.87 (57)	374.79 (55)	399.17 (54)	335.95 (57)	322.59 (57)	314.42 (57)	337.83 (56)
58.	CO-25	347.52 (58)	359.59 (58)	380.94 (58)	329.65 (59)	316.71 (58)	308.36 (59)	331.65 (59)
59.	Triveni	345.97 (59)	414.89 (27)	435.94 (28)	330.86 (58)	316.56 (59)	309.73 (58)	332.62 (58)
60.	Jayathi	319.65 (60)	364.01 (57)	385.52 (57)	301.64 (60)	289.07 (60)	281.68 (60)	303.23 (60)

(Numbers in paranthesis indicate rank order.)

In the case of preparation *kozhukkatta* also the first two ranks goes to *Vyttila-3* (449.38) and *Hraswa* (417.34) respectively while the last rank again goes to variety *Jayathi* (281.68).

Hybrid derivatives *Vyttila-3* (420.77) and *Hraswa* (437.34) were found to be superior ones with an index score of 420.77 and 437.34 respectively indicating their suitability for the preparation *appam*. In this case also the variety Jayathi scored the lowest rank (303.23).

In general, the hybrid derivatives *Vyttila-3, Hraswa, Onam* and *Veluthari Thavalakannan* were found to be highly acceptable on the basis of physical, cooking and organoleptic characteristics whereas hybrid derivatives *Jayathi, Nila* and traditional variety *Kavunginpoothala* and other improved variety *CO-25* were less acceptable on the basis of above characteristics for the various rice based preparations.

4.6.3 Index based on nutritional composition (Table 26)

In the case of raw rice, the index score constructed ranged between 1174.15 to 972.32. The highest score (1174.15) was scored by hybrid derivative *Vyttila-3* followed by *Veluthari Thavalakannan* (1140.52). The lowest score was secured by hybrid derivative *Bhadra* (972.32)followed by *Asha* (1033.22).

As in the case of raw rice, in the case of parboiled rice also, the highest rank was scored by *Vyttila-3* (1180.61). The lowest score was again secured by hybrid derivative *Bhadra* (994.69) and *Asha* (1040.45). The index score developed for parboiled rice varieties were found to be better than their raw form.

4.6.4 Comprehensive index based on physical, cooking, organoleptic characteristics and nutritional composition (Table 27)

The varieties selected for the nutrient analysis were also selected for developing a comprehensive quality index based on physical, cooking, organoleptic and nutritional characteristics. *Vyttila-3* and *Veluthari thavalakannan* were found to be the superior varieties of rice both in raw and parboiled form. The variety *Hraswa* assumed 3rd rank in raw rice shifted to 7th rank in parboiled rice. When *Kutticheradi* was ranked 4th among raw rice it assumed 3rd rank in parboiled rice. The rank of *Remya, Aruvakkari* and *Asha*

Table 26 Index developed from nutritional composition of rice in selected varieties

Sl. No	Variety	Raw	Parboiled
1.	Vyttila-3	1174.15 (01)	1180.61 (01)
2.	Veluthari Thavalakannan	1140.52 (02)	1149.25 (05)
3.	Jayathi	1107.44 (03)	1160.37 (03)
4.	Jaya	1107.09 (04)	1163.77 (02)
5.	Thekkencheera	1092.55 (05)	1129.42 (06)
6.	Aryan	1088.35 (06)	1116.53 (08)
7.	Hraswa	1078.15 (07)	1076.99 (13)
8.	Kutticheradi	1076.50 (08)	1156.06 (04)
9.	Aruvakkari	1072.10 (09)	1103.02 (09)
10.	Nila	1069.77 (10)	1098.46 (11)
11.	Remya	1062.43 (11)	1118.64 (07)
12.	Aruna	1061.89 (12)	1102.92 (10)
13.	Bhagya	1061.88 (13)	1061.13 (15)
14.	Chuvannari Thavalakannan	1045.27 (14)	1089.71 (12)
15.	Kavunginpoothala	1040.24 (15)	1067.22 (14)
16.	Asha	1033.22 (16)	1040.45 (16)
17.	Bhadra	972.32 (17)	994.69 (17)

(Numbers in paranthesis indicate rank order.)

Table 27 Quality index developed for selected rice varieties from physical, cooking, organoleptic and nutritional qualities.

Sl. No	Variety	Raw rice	Parboiled rice
1.	Vyttila-3	1245.22 (01)	1740.54 (01)
2.	Veluthari Thavalakannan	1159.01 (02)	1636.07 (02)
3.	Hraswa	1108.07 (03)	1564.69 (07)
4.	Kutticheradi	1071.12 (04)	1623.95 (03)
5.	Remya	1067.76 (05)	1586.24 (05)
6.	Aryan	1065.88 (06)	1559.74 (08)
7.	Chuvannari - Thavalakannan	1062.50 (07)	1581.80 (06)
8.	Jaya	1062.31 (08)	1619.80 (04)
9.	Bhagya	1054.34 (09)	1494.80 (14)
10.	Thekkencheera	1050.65 (10)	1542.90 (11)
11.	Aruna	1049.40 (11)	1550.98 (10)
12.	Aruvakkari	1022.56 (12)	1516.78 (12)
13.	Asha	1021.06 (13)	1510.81 (13)
14.	Jayathi	999.45 (14)	1556.63 (09)
15.	Nila	995.63 (15)	1476.63 (16)
16	Bhadra	966.38 (16)	1492.03 (15)
17.	Kavunginpoothala	962.97 (17)	1475.86 (17)

(Numbers in paranthesis indicate rank order.)

remained the same in both the cases. Varieties such as *Nila, Bhadra* and *Kavunginpoothala* remained in the lowest ranks in both the cases. In the case of certain other varieties *Bhagya* and *Jayathi* there was a great shift in the ranks with respect to raw and parboiled rice varieties due to variations in the different quality parameters. The index score developed for all the selected varieties of parboiled rice were better than the indices obtained for the same variety in raw form. This might be due to increase in thousand grain weight, head rice yield, elongation ratio, calorific value, phosphorus, calcium and iron content in the rice varieties after parboiling.

These findings will be of immense practical significance to evolve new varieties based on the above characteristics so that traditional varieties like *Veluthari Thavalakannan, Kutticheradi, Aryan* and *Chuvannari Thavalakannan* can be better utilized in the future plant breeding programmes.

SUMMARY

SUMMARY

A study on "A multi variate approach to define the quality of rice" was carried out to assess the major quality parameters such as physical characteristics, cooking characteristics, organoleptic qualities and nutritional composition. Thirty hybrid derivatives, twenty eight traditional/local varieties and two other improved/market varieties were selected for the study. The suitability of these rice varieties for various rice based preparations were also assessed. Divergence of rice varieties with respect to organoleptic qualities using raw and parboiled rice were also worked out.

The physical characteristics studied were thousand grain weight and grain dimension ratio (L/B ratio) in unhusked rice and thousand grain weight, grain dimension ratio (L/B ratio), head rice yield and moisture in husked rice.

1. Thousand grain weight of unhusked rice was found to be higher in hybrid derivatives of rice viz., *Reshmi* and *Vyttila-3* when compared to traditional and other improved varieties. Parboiling had significant positive effect on thousand grain weight

2. The grain dimension ratio of unhusked rice was found to be higher in raw sample than that of the parboiled samples. The highest grain dimension ratio was observed in traditional variety *Aranmula local.*

3. Thousand grain weight of husked rice was found to be higher in hybrid derivatives of rice (eg:-*Reshmi* and *Vyttila-3*) when compared to traditional and other improved varieties. Parboiling had a significant positive effect on thousand grain weight.

4. The quantum of wastage that occurs during dehusking indicates quality. In the case of raw samples, the mean values were found to be higher in hybrid derivatives when compared to traditional and other improved varieties. Maximum loss was observed in hybrid derivative *Red Triveni.* Process of parboiling significantly decreases milling loss.

5. There was no wide variation in the grain dimension ratio between the raw and parboiled husked rice samples. The grain dimension ratio of raw samples were generally higher than that of the parboiled samples. Traditional variety *Aranmula local* and hybrid derivative *Neeraja* were found to have higher grain dimension ratio when compared to hybrid and other improved varieties.

6. Head rice yield was found to be higher in traditional varieties. The highest head rice yield was observed for variety *Chuvannari Thavalakannan* followed by variety *Vyttila-3*. A marked increase in the head rice yield was noticed in all the varieties when parboiled.

7. The moisture content was found to be high in traditional variety *Kuruwa* and a comparatively higher moisture content was observed in traditional varieties. A marked decrease in moisture content was observed when parboiled.

8. Hybrid derivatives such as *Hraswa, Remya, Vyttila-1, Bharathy* and *Vyttila-3* and traditional varieties such as *Kutticheradi, Elappapoochemban, Sinduram, Veluthari Thavalakannan, Chuvannari Thavalakannan, Kattamodan, Vadakken Chitteni, Aryan* and *Chenkayama* were found to have favourable values for the four indicators studied under physical characteristics.

9. Among the various indicators studied under physical characteristics, thousand grain weight and L/B ratio were found to be the two major determinants with a positive effect on the grain size either in raw or in parboiled form.

Different cooking characteristics studied were optimum cooking time, gruel loss, gelatinization temperature, viscosity, water uptake, volume expansion, elongation ratio and elongation index. A higher value for water uptake, volume expansion, elongation ratio and elongation index and lower value for optimum cooking time, gruel loss, gelatinization temperature and viscosity are generally preferred.

10. The optimum cooking time did not vary much among traditional and hybrid derivatives of rice. Other improved varieties took less time for cooking. The optimum cooking time was found to be increased with parboiling.

11. The gruel loss was higher in traditional varieties in raw form when compared to hybrid and other improved varieties. The gruel loss was found to be decreased as a result of parboiling.

12. Hybrid derivatives were found to have higher gelatinization temperature than traditional and other improved varieties. Parboiling was found to increase the gelatinization temperature of hybrid and traditional varieties of rice samples.

13. The viscosity was found to be higher in traditional varieties when compared to hybrid and other improved varieties of rice. A slight increase in the viscosity was observed in hybrid and market varieties as a result of parboiling.

14. Hybrid derivatives were found to have higher water uptake than traditional and other improved varieties. Parboiling was found to decrease the water uptake in all the rice varieties.

15. The volume expansion after cooking was found to be influenced by the water uptake and this expansion was higher in hybrid derivatives when compared to traditional and other improved varieties. The volume expansion was found to be decreased as a result of parboiling.

16. No significant variation in elongation ratio was observed among hybrid, traditional and other improved varieties. A slight increase in the elongation ratio was observed in hybrid derivatives of rice as a result of parboiling while no change was noticed in traditional and other improved varieties.

17. Variation in elongation index was also not significant among hybrid and traditional varieties of rice. A slight increase in the elongation index was observed in hybrid and traditional varieties of rice when parboiled.

18. Hybrid derivatives such as *Hraswa, Remya, Vyttila-1, Vyttila-3, Bharathy, Jaya, Triveni, CSRC collection, Red Triveni, Sabari* and *Jyothi* and traditional varieties such as *Kattamodan, Chitteni, Kutticheradi, Chenkayama, Aranmula local, Chettivirippu, Kuruwa, Chuvannari Thavalakannan, Ponnaryan, Veluthavattan, Vadakken Chitteni* and Aryan were found to satisfy the indicators selected under cooking characteristics.

19. Rice grains studied under hybrid derivatives were found to give better performance for indicators such as gruel loss, viscosity, water uptake and volume exapansion.

20. The hybrid derivatives of larger grain size were found to have higher values for optimum cooking time, greater water uptake, volume expansion and less gruel loss when compared to smaller grains of traditional varieties.

Appearance , colour, flavour texture and taste were the quality attributes tested to decide the acceptability of the rice samples. Cooked rice (raw), cooked rice *(parboiled), iddli, dosa, puttu, kozhukkatta* and *appam* were various preparations attempted to ascertain the suitability.

21. Hybrid derivatives such as *Bharathy, Jayathi, Jyothi, Kanakom, Neeraja, Swarnaprabha, Swarnamodan, Vyttila-1* and *Vyttila-3* and traditional varieties such as *Aruvakkari, Aryan, Chenkayama, Chuvannamodan, Elappapoochemban, Kattamodan, Thrisur local-1, Thekken, Vadakken Chitteni, Vellari* and *Veluthavattan* and other improved varieties such as *CO-25* and *Mashuri* were found to be highly suitable where as varieties like *Aryankali, Remya* and *Chuvannari Thavalakannan* were found to be unsuitable for the preparation cooked rice using raw rice.

22. Process of parboiling had an impact on the quality of rice and [illegible] hybrid derivatives such as *Aruna, Asha, Bhadra, Kanakom, Karthika, Vyttila-1, Vyttila-3* and *Pavizham* and traditional varieties such as *Chenkayama, Cheriya Aryan, Chuvannamodan, Veluthavattan* and *Elappapoochemban* were found to be highly acceptable. However varieties such as *Kanakom,*

Chenkayama, Chuvannamodan and Elappapoochemban were found suitable for cooked rice in raw as well as in parboiled form. Varieties such as *Bharathy, CSRC collection, Kuruwa, Kavunginpoothala, Navara* and *Thrissur local-2* were found unsuitable for the preparation cooked rice using parboiled rice.

23. For fermented and steamed preparation, *(iddli)* varieties like *Annapoorna, Aruna, Jayathi, Neeraja, Nila, Pavizham, Reshmi, Swarnaprabha, Swarnamodan, Vyttila-1, Vyttila-3, Chenkayama, Cheriya Aryan, Chitteni, Aryan, Chuvannamodan, Chuvannari Thavalakannan, CO-25* and *Mashuri* were found to be highly acceptable where as varieties like *CSRC collection, Jyothi, Onam, Red Triveni, Chettiviripppu* and *Kuruwa* were found to be unsuitable ones. Traditional varieties such as *Chenkayama, Chuvannamodan* and *Elappapoochemban* suitable for the preparation cooked rice either in raw or parboiled form were also found suitable for the preparation *iddli.*

24. When the fermented batter was used for preparing dosa by shallow frying, varieties like *Aruna, Jayathi, Neeraja, Reshmi, Swarnaprabha, Swarnamodan, Vyttila-1, Vyttila-3, Chenkayama, Aryan, Chitteni, Chuvannamodan, Elappapoochemban, Kattamodan, Kavunginpoothala, Ponnaryan, Vellari, Veluthavattan, Veluthari Thavalakannan* and *CO-25* were found suitable as in the case of *iddli.* Besides these varieties, rice samples such as *Hraswa, Triveni, Kutticheradi* and *Thrissur local-1* were also found suitable for this preparation. Varieties like *CSRC collection* and *Chettivirippu* were found unsuitable for *iddli.* In addition to this, varieties such as *Makom, Remya* and *Navara* were also found unsuitable.

25. The highly acceptable varieties such as *Neeraja, Swarnamodan, Vyttila-1, Vyttila-3, Chenkayama, Chitteni, Kattamodan, Kavungin Poothala, Vellari, Veluthavattan* and *CO-25* suitable for *iddli* and *dosa* were also found suitable for powdered, roasted and steamed preparation like *puttu.* In addition to this, varieties such as *Annapoorna and Thrissur local-1* were also

found suitable ones. Hybrid derivative *CSRC collection* was found unsuitable for this preparation.

26. The highly suitable varieties such as *Vyttila-1, Vyttila-3, Chitteni, Kavunginpoothala, Vellari* and *CO-25* for *iddli, dosa, puttu* were also found suitable for powdered, roasted and boiled preparation *(kozhukkatta)*. Besides these, varieties such as *Swarnaprabha, Cheriya Aryan, Thrissur local-1, Ponnaryan, Thekkencheera* and *Veluthari Thavalakannan* were found suitable for this preparation also. The unsuitable variety for this preparation was *CSRC collection.*

27. For the baked preparation *(appam)*, varieties such as *Vyttila-1, Kavunginpoothala, Vellari, and CO-25* were found highly suitable as in the case of *iddli, dosa, puttu* and *kozhukkatta.* In addition to this, varieties such as *Annapoorna, Bhagya, Jayathi, Jyothi, Kanakom, Lakshmi, Makom, Neeraja, Onam, Red triveni, Remya, Reshmi, Sabari, Sagara, Swarnaprabha, Swarnamodan, Triveni, Vyttila-3, Aruvakkari, Aryan, Chenkayama, Cheriya Aryan, Chettivirippu, Elappapoochemban, Kattamodan, Kuruwa, Navara, Thekken, Veluthavattan, Thrissur local-2, Aranmula local, CO-25* and *Mashuri* were also found suitable ones. In this case also, the variety *CSRC collection* was found unsuitable.

28. The overall acceptability of the seven preparation revealed that variety *Veluthavattan* and *Vyttila-1* were found to be highly acceptable and suitable ones where as variety *CSRC collection* was found unsuitable for fermented (ie *iddli, dosa* and *appam)* steamed *(puttu)* and boiled *(kozhukkatta)* preparation.

29. Application of moist heat during different cooking techniques have resulted in the hydrolysis and decomposition of major nutrients like carbohydrates and proteins and this has helped to retain the characteristic flavour and taste which are acceptable in preparation of cooked rice (parboiled).

30. Procedures adopted in baking *(appam)* and steaming *(iddli and puttu)* had helped to bring about physical and chemical changes in the grains whereby colour, texture and appearance had improved as indicated in the scores for these preparations.

31. During the process of fermentation, by the action of micro organisms on protein and fat rice samples lost their original colour resutling in a brownish yellow colour. Further procedures adopted in these preparations had helped to enhance their sensory qualities due to changes in starch and protein.

D^2 analysis is useful to group the divergent rice varieties into various clusters based on the organoleptic quality such as appearance, colour, flavour, texture and taste (raw and parboiled rice).

32. D^2 analysis was also carried out to find out the divergence in rice varieties with respect to organoleptic qualities both in raw and parboiled rice varieties. In the case of raw rice, the sixty varieties were grouped into six clusters. Fifty one varieties were included in Cluster I, three in Cluster II, two each in clusters III and IV and one each in clusters V and VI. The varieties which exhibited minimum divergence based on the quality attributes such as appearance, colour,flavour, texture and taste got clustered together. Cluster V is superior for quality attributes colour, flavour and taste indicating that this cluster is superior to the rest of the clusters. Cluster IV recorded lowest scores for appearance, colour and texture.

33. In the case of parboiled rice altogether ten clusters were formed. Forty one varieties were included in Cluster I, seven in cluster II, two each in clusters III, IV, V and VI and one each in clusters VII, VIII, IX and X. Cluster V showed high mean values for appearance and colour where as cluster II exhibited high values for texture and taste indicating that cluster V and II were superior to the rest of the clusters in respect of their quality attributes. Cluster VI recorded lowest mean scores for appearance, texture and taste.

The D^2 analysis carried out based on organoleptic characteristics revealed that thirty five varieties were found to be homogeneous with respect to the above qualities for the preparation of cooked rice using raw and parboiled rice.

34. The sixty varieties of rice were clustered on the basis of selected physical and cooking characteristics and representative samples were taken from each cluster for nutrient analysis. Altogether ten clusters were formed, of which the first and second clusters included maximum varieties 21 and 20 respectively while the last three clusters consisted only of single varieties.

The nutritional composition of rice varieties were ascertained by estimating calorific value, protein, starch, total amylose, amylose: amylopectin ratio, crude fibre, total ash, phosphorus, iron and calcium.

35. The assessment of calorific value of seventeen rice varieties revealed that the traditional varieties of rice gave higher values for calories when compared to hybrid derivatives. The highest calorific value was noticed in traditional variety *Thekkencheera*. Process of parboiling had a positive influence on the calorific value of all the seventeen rice varieties..

36. The protein content was found to be higher in hybrid derivatives *(Remya* and *Bhagya)* and process of parboiling had a negative effect on the protein content.

37. A wide variation was observed in the starch content of the different rice varieties. Traditional varieties were found to have higher starch content when compared to hybrid derivatives. Parboiling had a negative influence in lowering the starch content.

38. Hybrid derivatives had higher amylose content when compared to traditional varieties. Parboiling was found to decrease the total amylose content in all the seventeen rice varieties.

39. The assessment of amylose: amylopectin ratio varied significantly among rice varieties. Traditional rice varieties had a lower amylose-amylopectin ratio indicating the quality of rice. Parboiling didn't much affect the amylose -amylopectin ratio.

40. The crude fibre content was found to be higher in traditional varieties when compared to hybrid derivatives. No significant variation was observed after parboiling.

41. Significant variation in ash content was observed in rice varieties. The ash content was found to be more in hybrid derivatives and parboiled rice samples were found to retain more ash content in all the seventeen varieties of rice when compared to raw samples.

42. Hybrid derivatives of rice were observed to have higher values for minerals viz., phosphorus, iron and calcium. Parboiling, in general, was found to conserve phosphorus, iron and calcium content of the grain.

Discriminant function of Fisher was used to discriminate the various varieties of rice based on multiple characters relating to the quality parameters and individual indices were developed for quality parameters and also for various rice based preparations.

43. In the case of index score developed based on physical characteristics, the highest rank was secured by *Vyttila-3* followed by *Chuvannari Thavalakannan* and *Hraswa* while the lowest rank was scored by *Kavunginpoothala* followed by Thekken in raw as well as in parboiled varieties.

44. Based on cooking characteristics, the highest index score was obtained for *CSRC collection* while the lowest rank was scored by *Ponnaryan* in raw rice. *Vyttila-3* and *CSRC collection* scored the top most ranks while lowest ranks by *Elappapoochemban* and *Neeraja* in parboiled rice.

45. While considering the index scores of organoleptic characteristics, *Veluthavattan* scored the highest rank followed by *Vyttila-1* and the lowest score was secured by *CSRC collection* and *Chettivirippu*.

46. In the case of cooked rice using raw rice, hybrid derivative *Vyttila-3* scored the Ist rank followed by hybrid derivative *Hraswa*. The lowest rank was secured by *Jayathi*.

47. While in the case of cooked rice (parboiled), Ist rank was secured by hybrid derivatives *Vyttila-3* followed by *Bhadra*. Hybrid derivative *Nila* scored the lowest rank.

48. Hybrid derivative *Vyttila-3* followed by *Bhadra* scored first two ranks indicating its suitability for the preparation *iddli*. The hybrid derivative *Nila* was found to be least acceptable for the above preparation.

49. As in the case of cooked rice (raw), in the case of preparation of dosa also the same trend was noticed showing that hybrid derivative *Vyttila-3* secured the highest rank followed by *Hraswa*. In this case also the lowest rank goes to hybrid derivative *Jayathi*.

50. For the preparation *puttu*, the hybrid derivatives *Vyttila-3* and *Hraswa* were found to be the superior ones and the hybrid derivative *Jayathi* the least acceptable one.

51. *Vyttila-3* and *Hraswa* were ranked high for the boiled preparation called *kozhukkatta* while hybrid derivative *Jayathi* was found highly unsuitable for this preparation.

52. Hybrid derivatives *Vyttila-3* and *Hraswa* were found to be the superior ones indicating its suitability for the preparation called *appam*. Variety *Jayathi* scored the lowest rank in this preparation.

53. The index score developed for the nutritional composition of rice revealed that hybrid derivative *Vyttila-3* followed by *Veluthari Thavalakannan* were

superior ones among different raw rice samples and lowest score was secured by hybrid derivative *Bhadra* followed by *Asha*.

54. After the process of parboiling also *Vyttila-3* was found to be superior and the lowest rank was found in hybrid derivative called *Bhadra* followed by *Asha*.

55. A comprehensive index was also developed based on physical, cooking, organoleptic and nutritional composition of selected rice varieties (seventeen). Among the seventeen selected, hybrid derivatives like *Vyttila-3, Hraswa* and *Remya* were found to be superior with high index scores. Apart from these varieties, traditional varieties like *Veluthari Thavalakannan, Kutticheradi* and *Chuvannari Thavalakannan* were also found to obtain high index scores. Hybrid derivatives such as *Bhadra, Nila, Jayathi, Asha* and traditional variety like *Kavunginpoothala* were found to be least acceptable on the basis of index scores obtained. The index score developed for all the seventeen varieties of rice after parboiling were better than the indices obtained for the same variety in raw form.

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* Original not seen

APPENDICES

APPENDIX - 1

Specimen evaluation card for triangle test

Name :   Date

Product :   Time

Two of the three samples are identical

Determine the odd sample

Pair No.	Code No. of Samples	Code No.of Odd sample
1.		
2.		
3.		
4.		

(Signature)

APPENDIX - 2

Specimen evaluation card for composite scoring test

Name Date

Product Time

Assign scores for each sample for various characteristics

Quality attributes	Maximum Score	Code No. of samples 1	2	3	4	5	6	7	8
Appearance	5								
Colour	5								
Flavour	5								
Texture	5								
Taste	5								
Total	25								

Comments

(Signature)

Number of panel members selected : 10

Number of replications : 2

APPENDIX - 3

Physical characteristics of rice varieties (unhusked and husked)

Abstract of ANOVA

	Mean Square			
Character	**Variety (Va)**	**Processing methods (Pr)**	**Va x Pr**	**Error**
DF	59	1	59	120
Thousand grain weight (unhusked rice)	47.371**	21.969**	0.276**	0.194
Thousand grain weight (husked rice)	27.377**	51.992**	0.345**	0.004
Head rice yield	518.333**	23553.16**	227.578**	13.679
Moisture	2.524**	15.234**	2.818**	0.004

** Significant at 1% level.

APPENDIX - 4

Physical characteristics of rice varieties (unhusked and husked)

Abstract of ANOVA

Character	Mean Square			
	Variety (Va)	Processing methods(Pr)	Va x Pr	Error
DF	59	1	59	1080
L/B ratio (unhusked rice)	2.982**	8.795**	0.028**	0.013
L/B ratio (husked rice)	1.749**	3.279**	0.042**	0.41

** Significant at 1% level

APPENDIX - 5

Cooking characteristics of rice varieties

Abstract of ANOVA

Character	Mean Square			
	Variety (Va)	Processing methods(Pr)	Va x Pr	Error
DF	59	1	59	120
Optimum cooking time	170.093**	21888.6**	68.049**	1.742
Water uptake	1.483**	8.103**	0.117**	0.039
Volume expansion	1.591**	8.25**	0.159**	0.039
Gruel loss	10.962**	655.381**	5.504**	0.206
Gelatinization-temperature	91.694**	191.75**	14.261**	0.716
Viscosity	0.279**	0.0056**	0.235**	0.0005
Elongation ratio	0.073**	0.011	0.005	0.023
Elongation index	0.076**	0.007	0.005	0.023

** Significant at 1% level

APPENDIX - 6

Correlation matrix (Physical and Cooking Characteristics)

	H.R.Y	O.C.T	W.U	V.E	G.L	G.T	Mo	VY	T.G.W	E.I	E.R
O.C.T	0.435**										
W.U	-0.391**	-0.117									
V.E	-0.373**	-0.116	0.971**								
G.L.	-0.382**	-0.514**	0.051	0.054							
G.T	0.016	0.182**	0.139*	0.129*	0.153*						
Mo	-0.164*	-0.155*	0.276**	0.267**	0.162*	0.054					
V.Y	0.021	-0.070	0.049	0.057	0.029	-0.058	-0.014				
T.G.W	0.090	0.294**	-0.097	-0.096	-0.023	0.137*	0.036	-0.048			
E.I	0.066	-0.095	-0.123	-0.104	-0.029	-0.169**	-0.036	-0.135*	-0.211**		
E.R	0.077	-0.097	-0.126	-0.107	-0.035	-0.159*	-0.036	-0.124	-0.211**	0.993**	
L/B ratio	0.111	0.016	-0.099	-0.088	-0.033	0.023	-0.092	0.046	0.092	-0.107	-0.109

Values of r for different levels of significance

$r_{238},0.05$ = 0.129   *Significant at 5% level

$r_{238},0.01$ = 0.168   **Significant at 1% level

Abbreviations

H.R.Y	Head rice yield	O.C.T	Optimum cooking time
W.U	Water uptake	V.E	Volume expansion
G.L	Gruel loss	G.T	Gelatinization temperature
Mo	Moisture	Vy	Viscosity
T.G.W	Thousand grain weight	E.I	Elongation index
E.R	Elongation ratio		

APPENDIX - 7

Nutritional composition of rice varieties

Abstract of ANOVA

	Mean Square			
Character	Variety (va)	Processing methods(Pr)	Va x Pr	Error
DF	16	1	16	34
Calorific value	1152.438**	4715.50**	78.875**	4.103
Protein	3.983**	0.751**	0.017**	0.0005
Starch	122.638**	36.344**	1.846	2.125
Amylose	7.439**	79.402**	0.586	0.0001
Amylose-Amylopectin ratio	0.0056**	0.0043**	0.0016**	0.0001
Crude fibre	0.041**	0.00005	0.0001	0.00007
Total ash	0.024**	0.145**	0.0007*	0.0003
Calcium	0.760**	4.292**	0.0116**	0.005
Phosphorus	663.844**	7767.125**	119.234**	1.574
Iron	0.237**	0.911**	0.025**	0.008

** Significant at 1% level

* Significant at 5% level

APPENDIX 8
Glossary

A. Food terms

Iddli : Steamed product prepared from fermented batter made of parboiled rice and black gram dhal.

Dosa : Pan-fried product usually prepared from a fermented batter made of raw rice and black gram dhal.

Puttu : a steamed product prepared from powdered and roasted rice flour. Coconut scrapings are also added.

Kozhukkatta : a boiled product prepared from powdered and roasted rice flour. Coconut scrapings and cumin seeds are also added.

Appam : a baked product prepared from fermented batter made of raw rice. Sugar is also added.

B. Other terms.

Fermentation : Chemical decomposition brought abou: by enzymes.

Hybrid : strain (or breed) obtained by cross fertilization of two different strains (or breeds).

Virippu or Khariff rice : I crop season of rice in Kerala coinciding with South West monsoon season from May-June to August-September. High yiedling photo insensitive varieties are grown.

Mundakan or rabi rice : II crop rice where early stage is under rainfed condition conninciding with North East monsoon and later period grown with irrigation from September-October to December-January. High yielding photo sensitive varieties are grown.

ABSTRACT

A study on "A multi variate approach to define the quality of rice" was carried out to assess the major quality parameters such as physical characteristics, cooking characteristics, organoleptic qualities and nutritional composition. Sixty rice varieties (thirty hybrid derivatives, twenty eight traditional/local varieties and two other improved/market varieties) were selected.

The programme envisaged not only a detailed study on different quality parameters like physical characteristics, cooking characteristics, organoleptic qualities but also the suitability of the varieties to rice based preparations. Importance was paid to nutritional quality of the varieties. All the above indicators were tested both for raw as well as for parboiled rice.

Among the various indicators studied under physical characteristics, in general, thousand grain weight was found to be higher in hybrid derivatives of rice while head rice yield and moisture content in traditional varieties. Process of parboiling was found to increase the thousand grain weight and head rice yield.

Less cooking time, less gruel loss, lower viscosity, higher elongation index and elongation ratio were noticed in other improved varieties while higher water uptake and volume of expansion after cooking, a desirable trait were noticed in hybrid derivatives of rice. As a result of parboiling, optimum cooking time, elongation index and gelatinization temperature were found to increase and there was a decrease in gruel loss, volume expansion and water uptake due to parboiling.

Rice based preparations using different cooking methods such as boiling, fermenting and steaming, fermenting and shallow frying, powdering, roasting and steaming, powdering, roasting and boiling and baking were attempted. The overall acceptability of the quality attributes revealed that market varieties were found to obtain highest score, followed by traditional and hybrid derivatives.

Cluster analysis was carried out to group/cluster the various rice varieties based on their multiple characters. The D^2 analysis based on organoleptic qualities revealed that

thirty five varieties were found to be homogeneous with respect to the above qualities for the preparation of cooked rice using raw and parboiled rice.

Seventeen varieties were selected for nutrient composition on the basis of D^2 analysis using physical and cooking characteristics of rice varieties. Parboiling had a positive influence on calorific value, ash and mineral content while negative effect on starch, amylose and protein in all the selected rice varieties.

Discriminant function approach was used to discriminate the various varieties of rice based on multiple characters relating to the quality parameters and individual indices were developed for quality parameters and also for various rice based preparations.

A comprehensive index was also developed based on physical, cooking, organoleptic and nutritional composition of selected rice varieties. Hybrid derivatives like *Vyttila-3, Hraswa* and *Remya* were found to obtain high index scores among the seventeen varieties. Apart from these, traditional varieties like *Veluthari Thavalakannan, Kutticheradi* and *Chuvannari Thavalakannan* were also found to obtain high index scores. Hybrid derivatives such as *Bhadra, Nila, Jayathi, Asha* and traditional variety *Kavunginpoothala* were found to be least acceptable on the basis of index scores obtained.