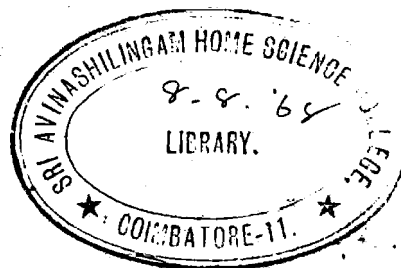


**COMPARISON OF THE NUTRITIVE VALUE OF DIFFERENTLY PROCESSED
PARBOILED RICE**

by

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I. INTRODUCTION

Rice, considered as the 'Queen among cereals', is one of the important food grains cultivated by man from the beginning of history. Rice is the staple and mainstay for half the world's population (Spring, 1966), Randhawa, (1960) and Patwardhan, (1961). The Food and Agriculture Organisation of the United Nations (FAO) (1966) points out that for hundreds of millions of people in Asia, the rice crop is virtually the sole livelihood.

Parthasarathy (1966) and FAO (1966) have estimated that for over 1,400 million people in the Far East, including the Mainland of China, where nine tenths of the world's rice production is concentrated and consumed, rice furnishes more than half the daily requirements of calories and a major portion of protein. According to the FAO (1966), the number of people depending solely on rice for food, approaches 200 million in India alone. The cultivation of rice occupies half to two-third of the arable land in India.

Rice is becoming increasingly popular also in many other parts of the world. Perhaps that is the reason why Cousins (1964) urged that any genuine improvement in human condition on this planet must be concerned with rice. The FAO had also designated

year 1966 as the International Rice Year. During that year intensive efforts were initiated to solve the problems of rice production, processing, wastage and utilisation for better nutrition of the people. These efforts have resulted in vast agronomic development in rice breeding.

Parboiling of rice is a traditional practice in South India and other parts. Parboiling has been defined by Charles (1930) as a method of steeping, boiling and drying paddy. It helps to harden the high yielding soft varieties of paddy before milling through gelatinisation of the starch in the rice grain, thereby minimising the breakage of the grain during subsequent polishing. Consequently the yield of head rice is increased up to five to ten per cent in the case of hard varieties. Parboiling thus adds to the total rice economy of the country. Besides the economic advantage, parboiling brings about a higher content of vitamins and minerals as compared to raw rice. Parboiled rice has better keeping quality since it is more resistant to insect attack than raw rice. (Central Food Technological Research Institute, Project Number seven).

Swaminathan and Bhagavan (1960), Ramamurthy and Gopalan (1966) and Prema (1967) have demonstrated that parboiled and dehusked rice contain higher quantities of minerals and vitamins than the corresponding raw samples of milled rice. The National Research Council (NR^C) of the U.S.A. (1945) has also shown that parboiled rice is better than raw rice because of its greater contents of thiamine and niacin.

The FAO (1954) has stated that parboiled rice contains two to four times as much thiamine as milled rice.

Patwardhan (1961) has stated that the practice of parboiling is old. The parboiling processes are still empirical with slight differences in the time allowed for soaking, temperature of steep water, renewal or otherwise of steep water and period of steaming.

Some studies on the standardisation of parboiling process are available. Revathi (1967) found that six hours 'cold soaking' followed by parboiling gave greater milling out turn than with three and twelve hours. Sarda (1965) and CFTRI (1959) observed that hot soaking for three hours at 70 to 75°C and then parboiling has the following advantages over the traditional method.

There is reduction in soaking time from two or three days in the 'cold soaking' method, and from one day in the 'double boiling' method, to three to four hours in the 'hot soaking' method. This reduction reduces the processing time considerably and makes for larger production of rice by minimising the breakage during milling. The development of bad smell through microbial spoilage in the three day soaking is avoided by this improved method. The labour cost is also reduced by seventy five per cent. The water requirements in this method are smaller than in the cold soaking method, as frequent changes of soak water are not necessary. Steam consumption is reduced by twenty five per cent.

While it has been proved that parboiling through these improved methods have several advantages, information is not available on the nutritive value of parboiled rice, processed by 'six hours cold soaking' and 'three hours hot soaking' method. Therefore this investigation was undertaken to find out the effect of cold and hot soaking process in the parboiling of paddy, on its nutritive value, calories, protein, iron, phosphorus and thiamine in terms of contents.

II. REVIEW OF LITERATURE

The literature relevant to this study is reviewed under the following headings:

- A. Cultivation of rice
- B. Nutritive value of rice
- C. Steps involved in the process of parboiling
- and D. Changes that occur during parboiling paddy
 - 1. Soaking of paddy
 - 2. Parboiling of paddy
 - 3. Drying of paddy
 - and 4. Dehusking of paddy

A. Cultivation of Rice

Rice is a member of the great family of grasses. It produces a fruit that for hundreds of millions of people epitomises the difference between plenty and scarcity, fulfilment and hunger, and life and death. Pal (1966) reported that the area of land under cultivation of rice in India is the largest being 3,38,59,000 hectares. She has cultivated rice since prehistoric times. Rice has always occupied a pre eminent place among her food crops covering now more than 30 per cent of the total annual cultivated area. Rice not only forms the mainstay of the diets of the majority of the people, but also bears a large influence on their life and economic conditions (Ghose et al 1960).

The Central Food Technological Research Institute(1953) has reported that paddy is essentially a crop which thrives in tropical regions. Nevertheless in sub-tropical countries such as Italy and Spain also paddy is being cultivated. Although rice has been cultivated throughout Asia, tropical yields are deplorably low by world standards (Jackson 1967). National average yields for countries in temperate zones such as Japan, Australia and the borders of the Mediterranean, range from four to six tonnes per hectare. The corresponding figures for tropical countries seldom exceed two tonnes per hectare. The average Indian yield is about 1.5 that of Thailand 1.6, and of the Philippines only 1.2 tonnes.

In recent years, the production of rice in India has not kept pace with its increasing population. Eighty per cent of her population are still dependent, directly or indirectly, upon agriculture. Ramiah (1966) observes that the increase in rice production has been offset by the population growth, resulting in bottlenecks in meeting the consumers' demands for rice.

Based on the findings of research carried out in the Outback Rice Research Station, Aduthurai Rice Breeding Farm and other Research Stations all over India several attempts have been initiated to grow more rice. The benefit of developing hybrid varieties of food grains has been realised by agricultural institutes and experimental farms in different parts of the country.

B. Nutritive Value of Rice

Even a small change in the nutritive value of rice can affect profoundly the overall nutritional quality of the diet and consequently the health of the people. An elementary knowledge of the rice grain structure would help a better understanding of the nutritive value of rice.

The rice grain, as obtained by mild dehusking of paddy, consists of three parts:

1. Germ
2. Pericarp or outer bran layer
- and 3. Endosperm or inner core of the grain.

The germ and the bran layers contain most of the protective nutrients such as vitamins and minerals while starch makes up the bulk of the inner core. The pericarp contains the bran with some oil in it and the germ also contains some fat. Different varieties of the commonly used rice, have approximately the following same composition (Rama Sastri, 1967) given in Table I.

TABLE I
NUTRITIVE VALUE OF RICE
(values per 100 grams of rice)

	Raw rice		Parboiled rice	
	Handpounded	Milled	Handpounded	Milled
Protein(g)	7.3	6.9	8.5	6.4
Fat, (g)	1.2	0.5	0.6	0.4
Carbohydrates, (g)	80.1	92.1	77.4	79.1
Calcium, (mg)	13.0	10.0	10.0	10.0
Phosphorus, (mg)	182.0	97.0	280.0	150.0
Thiamine, (mg)	0.21	0.11	0.27	0.21
Riboflavin, (mg)	0.16	0.06	0.12	0.09
Nicotinic acid, (mg)	2.5	1.0	4.0	3.8

Carbohydrates

According to Swaminathan and Bhagavan (1960) rice is the most important source of carbohydrate in the South Indian diets due to its high carbohydrate content. It is valuable chiefly as an economical source of energy. The percentage of carbohydrate varies depending upon conditions of growth and the processing methods adopted (Osee, 1959). Stanley and Cline (1950) point out that the starch is stored in the endosperm along with a little amount of protein, minerals and vitamins.

According to Harris and Loesecke (1960) starch is the principal constituent of the rice kernel, comprising over 85 per cent of the dry weight of the brown rice and over 90 per cent of the dry weight of polished rice. The starch of the most long-grain varieties contains 16 to 25 per cent amylose, whereas that of rice of the medium and short grain varieties is lower, that is, 12 to 15 per cent. Small amounts of cellulose are present in brown rice as constituents of the pericarp, but they are removed almost entirely during milling. Hemicellulose is found in the outer parts of the kernel and removed by milling.

Protein

The protein of rice, according to Miller (1960) is of great significance because 24 per cent of the total protein in the average Indian diet is derived from this source. Harris and Loesecke (1960) pointed out that the protein is present in fairly large concentrations in the embryo and the aleurone layers, but occurs to a much lower extent (6 to 8 per cent) in the starchy endosperm. The protein of polished rice is largely glutelin with small amounts of globulin and prolamin fractions.

The chemical composition and nutritive value of rice diets have been studied by Aykroyd et al (1940), Mason et al (1946), Done (1949), Kuppaswamy and Giri (1949), Desikachar et al (1956) and Wernick et al (1956). McCall and others have reviewed the chemical composition of rice upto 1951. These studies showed that rice is a poor source of protein. The protein content is lower than that in most varieties of wheat and maize. The total protein content of rice varies from six to nine per cent. Sadasivan and Srinivasan (1938) reported that coarse and coloured types of rice generally have more protein than the fine grain types.

The quality of rice protein has been studied by various workers. The FAO (1954) has summarised that the proteins of rice are of good quality and compare favourably with proteins of whole wheat and maize in amino acid content. According to Ramasastri (1967), although the protein content in rice is much less than that of wheat, the quality is superior to that of wheat protein, as judged by Protein Efficiency Ratio (PER) [(Swaminathan, (1937) and Basu and Basak (1937)].

Patwardhan (1961) points out that several reports of investigations have shown that the digestibility of rice protein is well over 90 per cent and its biological value is also comparatively high. Through digestibility trials with cereals and soya meal, Hsu and Kung (1948) concluded that rice had a higher biological value at 81.3 per cent, than millet and soya meal which had 70.6 per cent as the biological values. Mitra and Verma (1947) and Mitra et al (1948) registered a high biological value for rice protein in their human feeding trials.

The amino acid content of different varieties of rice vary considerably. The amino acid composition of rice has been studied by Block and Bolling (1951) and they recorded that rice is deficient in lysine and threonine. The protein content of successive peripheral layers of rice removed by the tangential abrasion process show in general that the protein concentration is higher near the periphery of whole grain (Normand et al, 1965) and there is no essential difference in amino acid content of the rice protein (Normand et al, 1966).

Fat

According to ^{Harris and} Loesecke (1960), fatty materials are found in significant amounts in the embryo (about 13 per cent lipid) and in the aleurone layers of rice. Brown rice contains 1.5 to 2.5 per cent oil which is a mixture of triglycerides. The lipids of rice contain three to nine per cent of fat located mostly in the outer bran layer and the germ.

Vitamins

Rice is a good source of several water-soluble vitamins which are concentrated in the embryo and the aleurone layers of the endosperm (Harris and Loesecke, 1960). According to Aykroyd (1966) noted a high thiamine content in rice ranging from 0.21 to 0.27 milligrams. The nicotinic acid ranged from 1.2 to 4.0 milligrams per 100 grams of rice.

Patwardhan (1961) is of the view that dietaries based on rice, have rice as the major source of thiamine apart from proteins and starch.

Sixty six per cent of thiamine is located in the embryo. So, the contribution rendered by rice to dietary thiamine is conditioned, by a number of circumstances, raw or parboiled and handpounded or milled. In raw rice, thiamine and niacin are concentrated mainly in the germ and pericarp. When these are removed by milling, the grain has lost most of its vitamins. In contrast in parboiled rice, the vitamin has diffused through the endosperm. Although germ and pericarp have been removed, the grain would still contain most of the vitamins (Rama Sastri, 1967).

On the other hand, hand pounded rice is richer in B vitamins, because the germ and bran are removed only partially. However, the bran layer is attached loosely to the grain. Therefore extensive washing will remove the vitamins contained in it. (Rama Sastri 1967). Ghose et al (1960) hold that the chief virtue of handpounding is that it gives a medium polished rice with a high thiamine content. Patwardhan (1961) reports that the time honoured but slow method of handpounding is less destructive in that it gives nutritionally a better product. The removal of bran layers is imperfect and hence the losses of nutrients also are less complete. In machine-milling, upto 75 per cent of thiamine may be lost in the bran, higher losses are not unknown. In handpounding, on the other hand, losses average about 25 per cent. The nutritive value of handpounded and dehusked rice have been found to be higher than that available after the removal of bran which is rich in the nutrients like thiamine, protein and mineral (1960).

Joachin and Kandiah(1929) proved the superiority of undermilled rice in terms of its protein and calcium contents.

TABLE II
LOSS OF NUTRIENTS DURING POLISHING

Rice	Protein (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Vitamins	
					Thia- min (μ g)	Nia- cin (mg)
a. Dehusked %	7.7	15	368	4.0	360	3.5
b. Handpounded %	7.2	13	146	2.2	190	2.2
c. Polished %	6.9	10	107	2.0	105	1.0

The above figures quoted by Patwardhan (1961) revealed that the chemical composition of nutrients of the handpounded or undermilled rice is superior to the polished rice. The utilisation of the nutrients especially the proteins in the undermilled rice has not been shown to be similarly superior.

In parboiled rice, losses of vitamins due to milling and washing are minimal. Parboiled rice according to Patwardhan (1961) may lose ten per cent of vitamins during milling and washing. During parboiling process 'B' vitamins especially thiamine, either diffuse into the inner core or adhere so firmly to the grain that even high milling does not bring about a significant loss of the nutrients (Rama Sastri, 1967).

Minerals

Rice is a poor source of calcium and iron, but contains considerable amounts of phosphorus, but the calcium and phosphorus ratio is unfavourable being 1:10 instead of the desirable 1:2. ~~Sundarajan~~ and Bhagavan (1960) and Ghose and coworkers (1960) have reported that rice contains negligible amount of calcium ranging from ten to twelve milligrams per cent. While the content of calcium is low in rice, its availability is high as shown by the early experiments of Majumdar and De (1938) who demonstrated through feeding trials, with different cereals, that rice gave the highest retention of calcium, 87.1 per cent when compared with 73.5 per cent for wheat.

The nature of phosphorus present in rice has been studied by Sundarajan (1938), Giri (1940) and Ahmed et al (1945). All these workers are of the view that aggravation of mineral imbalance in rice diets is due to the presence of phytin phosphorus in rice diet. Aykroyd (1964) considered that phytin phosphorus interferes with the absorption of dietary calcium and iron. Yet, Miller (1960) was of the opinion that phosphorus in rice has considerable significance in the diet.

C. Steps Involved in the Process of Parboiling

According to Gupta (1967) processing is an act or series of acts which make a commodity more suitable for final consumption. In other words, it adds utility to a commodity.

~~Iremb-aman~~ (1966) said that most foodstuffs are not fully acceptable in the raw form and have to be processed for better absorption, for improving their acceptance or for making them available for longer periods.

Such processing may entail some loss of certain nutrients, but, as a result of advances in nutrition, adverse effects of processing, whenever they exist, are becoming clearer and are being overcome by suitable procedures.

The FAO (1966) reported that processing rice, differs fundamentally from that of other important cereals. When milling wheat, the grains must be ground very fine to obtain flour, while in the processing and milling of rice, the aim is to keep the grain as nearly whole as possible.

Ghose et al (1960) pointed out that the beginning of the practice of parboiling in India, is not known with certainty, although the technical and nutritional advantages of parboiling were known to our ancients. The discovery of parboiling is one of the most important achievements in food science and the credit for this discovery belongs to India.

According to Davidson and Passmore (1966) 'parboiling' means the steaming or boiling of unhusked rice after preliminary soaking. Patwardhan (1961) described that the parboiling consists in soaking paddy in cold or warm water for varying lengths of time, followed by steaming till the grain becomes soft and partly or wholly cooked. The excess water is drained off and paddy is spread out to dry. Dried parboiled paddy is then hulled giving a product known as 'parboiled rice'. Mehan et al (1961) stated that the process as, pre-cooking and drying. Grist (1954), Milton et al (1952) and Kent and Amos (1947) pointed out that parboiling involves soaking, steaming, and drying paddy.

D. Changes that occur during parboiling paddy

According to FAO (1953), and Davidson and Passmore (1966), the B vitamins originally concentrated in the germ and aleurone layer diffuse through the grain and distribute in the core of the grain, thus ~~accounting~~ ~~ing~~ accounting for their greater retention in the parboiled milled rice. Hinton (1948) demonstrated that a redistribution of thiamine from germ, scutellum and aleurone layers took place during parboiling with the result that the endosperm became richer in thiamine than that of raw rice. He also confirmed Nicholl's suggestion that the germ and scutellum attained a firmer attachment to the rest of the grain during parboiling.

Rice parboiled before milling retains from 50 to 75 per cent of the original vitamin content as compared with 10 to 20 per cent in raw milled white rice (Stanley and Cline, 1950). Kik (1956) report^{ed} that substantial increases in thiamine, riboflavin and niacin resulted, when rice is parboiled.

Change in the colour occurring during the parboiling process, according to CPTRI (1956), is due to the pigments of the bran especially in the reddish varieties of rice, and the time and variety of heat treatment (Simpson 1965) given to the paddy during parboiling. The longer and more severe the heat treatment is, the greater the yellow tint in the finished rice. The colour is partly derived from the husk, but is mainly due to dextrinisation of the rice starch. According to Hogan (1965) the characteristic strong flavours and the accentuated yellow to amber colour of parboiled rice is due to the migration of substances from the husk into the endosperm during soaking and steaming.

Kurien et al (1964) found that parboiling treatment resulted in minor alterations in the dimensions of the milled grain. Therefore, the importance of an optimum steaming period to obtain a balance between swelling quality and increased yield of head rice has been emphasised.

1 Soaking paddy

CFTRI (1959) reported that in the traditional method of parboiling, paddy is kept soaked in cold water for two or three days. During this long period of soaking fermentation takes place and the rice picks up an undesirable odour which is rather offensive.

Instead of prolonged cold soaking process, the Central Food Technological Research Institute, Mysore, has shown that parboiling of paddy can be profitably done by soaking paddy in water at 70 - 75°C for 3 hours. The use of hot water at this temperature kills the micro-organisms which bring about the offensive odour.

Bandopadhyay and Ghose (1965) carried out the studies on the hydration of Indian paddy and pointed out that the rate of hydration has been found to decrease with increase in soaking period and to increase with rise in temperature. The highest initial rates of moisture uptake are independent of soaking temperature. The optimum soaking temperature is 75°C and the time taken for soaking at this temperature of different varieties of paddy does not exceed 3 hours. This period is not effected significantly by soaking at 80°C. At this temperature the grains burst, accelerating water pick up rates.

According to Meoham et al (1961) improper soaking resulted in incomplete gelatinisation and high proportions of broken kernels in the dried and milled product.

2. Parboiling of paddy

ICAR (1960) described the household practice of parboiling as that of usually raising the temperature of a mixture of paddy and water to simmering or boiling point and allowing it to cool gradually. The soaking water is then drained off and the paddy is dried. According to Charles (1930) and Patwardhan (1961) the traditional method of parboiling is steeping the paddy in warm water for a number of hours 15, 18 or 24 according to circumstances. The soaked paddy is steamed, dried in the sun and then milled or handpounded.

ICAR(1960) reported that in the commercial traditional methods of parboiling, two procedures are generally followed. They are 'cold soaking' with 'single boiling' and 'double boiling'. In the case of 'single boiling', the paddy is immersed in water for 2 or 3 days to permit the water penetrate into the grains thoroughly, steamed and then dried. In the 'double boiling' process, paddy is steamed and discharged into a large tank of cold water, or paddy is poured into warm water which has been heated to 60°C. The temperature then falls down to 30 - 40°C, becoming a fine medium for fungi, and emitting offensive smell. Thereafter it is steamed and dried. During steaming the bad odour is enhanced. ^{Jenqnarayana} (Iyer 1958 and ICAR 1960).

Desikachar et al (1957) have remarked that both the 'cold soaking' method and 'double boiling' method yield a bad smelling product. They assert that below 40°C, vigorous fermentation develops causing a bad smell. Simpson (1951) and the ICAR (1955) consider the colour, taste and

odour that render parboiled rice unpalatable to those accustomed to highly milled raw rice, as the disadvantages of parboiled rice,

In the year 1952, the Rice Technological Committee appointed by the Government of India sponsored a research programme to improve the methods of parboiling. The pioneering work was done by the committee and the suggestion made by it was, instead of soaking the paddy in cold water for two to three days, the temperature of the soak water could be increased to 65° - 70°C, whereby the soaking period is reduced to few hours and the fermented smell is completely eliminated. Desikachar and Subramanyam (1957) claimed that with minor changes in the customary methods, the principle of hot soaking could be applied as an improved method so as to be more economical and to give a wholesome product free from smell.

3. Drying of paddy

Varying methods are used for drying paddy with little uniformity or standardisation. The grains may be spread on the stone or concrete floor and dried in the direct sunlight or in the shade in a windy place.

According to Srinivasan (1935) the traditional practice of drying paddy is to dry the parboiled paddy in the sun for eight hours. Such drying has to be done with care because under or over drying will affect the milling quality. Ramaiah (1937) and FAO (1954) explain that if drying takes place too rapidly the outer parts of the grain may become dry while the interior may remain moist and the rice dried.

in this way may subsequently deteriorate rapidly. On the other hand, decomposition may occur if drying is too slow and the whole grain will remain moist for too long a period. According to Bhattacharya (1967) slow drying of parboiled paddy in the shade leads to excellent milling results (0.4 to 1 per cent broken in total milled rice), but rapid drying in hot air (40 - 80°C) or in the sun given very high breakages on milling (30 to 95 per cent).

Jai Pal Singh and Dharma Rao (1966) discourage drying paddy in the sun on cement floors as this process develops cracks inside the endosperm besides the losses caused by birds and rodents. Govindaswami (1966) reports that head rice recoveries due to milling of raw rice varied from 52.3 to 54.4 per cent in the case of shade drying of paddy and from 42 to 51.0 per cent in the case of sun drying. Through their experiments Govindaswami and Ghosh (1965) concluded that shade drying was the best.

Govindaswami (1966) and Bhattacharya (1967) state that the milling quality of parboiled paddy is seriously effected by improper conditions of drying. Loren (1950) recommends careful drying of parboiled paddy to result in high milling quality.

According to Govindaswami (1966) the optimum moisture content at the time of milling of paddy is important for getting maximum out-turn in milling. Pingale (1966) points out that the optimum moisture content at which the breakages are least is 14 per cent. It is generally considered that the maximum moisture content of rice for storage should not exceed 12 to 14 per cent (FAO 1953). Jai Pal Singh and Dharma Rao (1966) consider that the storage is easy and simple provided the moisture content is not higher than 14 to 15 per cent. International Cooperation

Administration (1967) reports that in the humid regions of South East Asia, moisture content must be controlled within 10 to 12 per cent, in other parts of Asia, Europe and the Western Hemisphere, 12 to 14 per cent is desirable for paddy rice. Where the moisture content exceeds the above limits, stored rice develops heat which causes discolouration and objectionable odours. The interior of grains becomes soft and subject to excessive breakage resulting in substantial losses in salability.

4. Dehusking paddy

Paddy after drying is processed into rice either by hand pounding or milling or dehusking using gear driven paddy dehusker.

Handpounding paddy

According to ICAR (1965) handpounding of paddy to remove the husk and the outer layers of bran is the oldest known method of converting paddy into rice.

Sarin (1966) reports that in India a larger proportion of rice consumed continued to be handpounded. According to one estimate, handpounded rice accounts for 40 per cent of the total production of rice although the consumption of machine-milled rice has increased in recent years.

Ghose et al (1960) states that milling of rice in small quantities in village homes using the various types of traditional equipment comes under the term "handpounding". The pounding breaks the outer husk and allows it to be separated by winnowing. Some of the germ and part of the pericarp is removed, the amount depending on the vigour and duration of the pounding.

Certain disadvantages of handpounding as compared with machine milling have to be pointed out in this connection. Lucius (1961) and Williams (1959) have warned that handpounding of rice does not always ensure a substantial retention of bran. Doris (1966) and Sontaky (1966) point out that handpounding produces a higher percentage of broken rice. According to Patwardhan (1961) the undermilled rice does not store well. The small amounts of fat in the grain tend to get rancid and spoil the quality of the product. Further, owing to the high humidity which exists at certain times of the year in most of the rice producing and consuming regions it falls an easy prey to bacterial and fungal attack. The restriction on milling of rice raises the problem of the high phytin content of rice interfering with the absorption of calcium and iron.

Milling paddy

The mechanical mill has nearly made the handpounding industry outmoded because it is very quick, efficient and above all labour saving (CFTRI, 1959). Doris (1966) remarked that about 20 million tons of paddy was processed by commercial mills in India.

Harris and Loesecke (1960) define milling as the series of mechanical operations that remove the hull, embryo, and the outer layers of the rice kernel. The object of rice milling is to remove the impurities, the husk and also the coloured outer epidermis of the rice grain, so as to give the rice the bright colour and the more pleasing appearance demanded by the consumer.

Milled rice consists of whole or broken kernels of rice from which the hulls and practically, all of the germ and bran layers have been removed.

International Cooperation Administration (1967) estimates when the rice grain is broken down in the successive stages of the milling process, about 25 per cent by weight of the original rough rice is hulls or husks. The balance is the husked kernel or brown rice. Harris and Loesecke (1960) explain that the degree of milling that is, the completeness with which the embryo and aleurone layers are removed, may be varied to suit the taste or customs of the consumer or to conform with official regulations.

Factors affecting the milling yield

Deodhar and Dandekar (1965) points out that both raw paddy and parboiled paddy are subjected to milling. The proportion of rice, broken rice and bran vary according to the material processed and the equipment used for processing. Parboiled paddy generally gives a higher out turn about five to ten per cent (Ghose et al) of whole rice due to the hardness of the parboiled grain than the raw rice. Davidson and Passmore (1966) and Douglas (1930) stated that parboiling splits the woody husk and renders its subsequent removal easier. Desikachar and Subramanian(1957), Lugui et al (1963), Te Tzu and Elisco (1965) and Govindaswami (1966) indicate that parboiling reduces breakage of grains. Parboiling paddy before milling, according to Brown (1965), increases the out turn of most Indian paddies by preventing milling losses associated with sun checks, soft starch and inferior milling equipment. Vijayan et al (1965) report that parboiled head rice recovery ranges from 46.5 per cent to 76.4 per cent depending on the variety.

III. EXPERIMENTAL PROCEDURE

The aim of this investigation was to find out the effect of 'six hours' cold soaking and 'three hours hot soaking' in the parboiling of paddy on the nutrient content of rice, either milled or handpounded. Accordingly the experimental procedure involved the following steps:

A. Obtaining parboiled rice

1. Procuring and cleaning the paddy
2. Selection of utensil
3. Soaking the paddy
 - a. Either cold soaking for six hours at room temperature, or
 - b. Hot soaking for three hours at 70° - 75°C.
4. Parboiling the paddy
5. Drying the paddy
6. Dehusking the paddy

Handpounding or milling paddy

7. Cleaning the rice.

B. Nutrient analysis of the differently processed parboiled rice for:

1. Calories
2. Protein
3. Phosphorus
4. Iron
- and 5. Thiamine.

A. Obtaining the Parboiled Rice

1. Procuring and Cleaning the Paddy

The paddy required for this study was calculated to be 150 Kg. purchased in one lot from the Central Farm of the State Agricultural College and Research Institute, Coimbatore. The PAO(1966) has reported that small stones and dirt going into the husker sheller cause increased breakage of rice and loss of out turn. Therefore the selected sample of paddy was cleaned in batches of six kilograms using a bambo winnower and made free from grit, dust and stones.

2. Selection of utensil

In order to increase the efficiency of the utensil in standardising the household method of parboiling, Revathi (1967) modelled an utensil as shown in Figure 1. That utensil was selected for the present study. It was of ten litres capacity.

A tap was fixed from the bottom of the utensil at the point 'A' in Figure 1, to drain the water. A perforated circular plate was fixed at the junction of the tap at 'A' to prevent paddy being washed out with the water. A lid was used to protect the paddy from being contaminated by dust and to maintain the temperature consistent to the extent possible while 'steaming' paddy.

3. Soaking the paddy

a. Cold soaking for six hours at room temperature

Six kilograms of paddy were weighed after cleaning and soaked in five litres of cold water at room temperature for six hours in the utensil shown in Figure 1. The utensil was kept open during soaking.

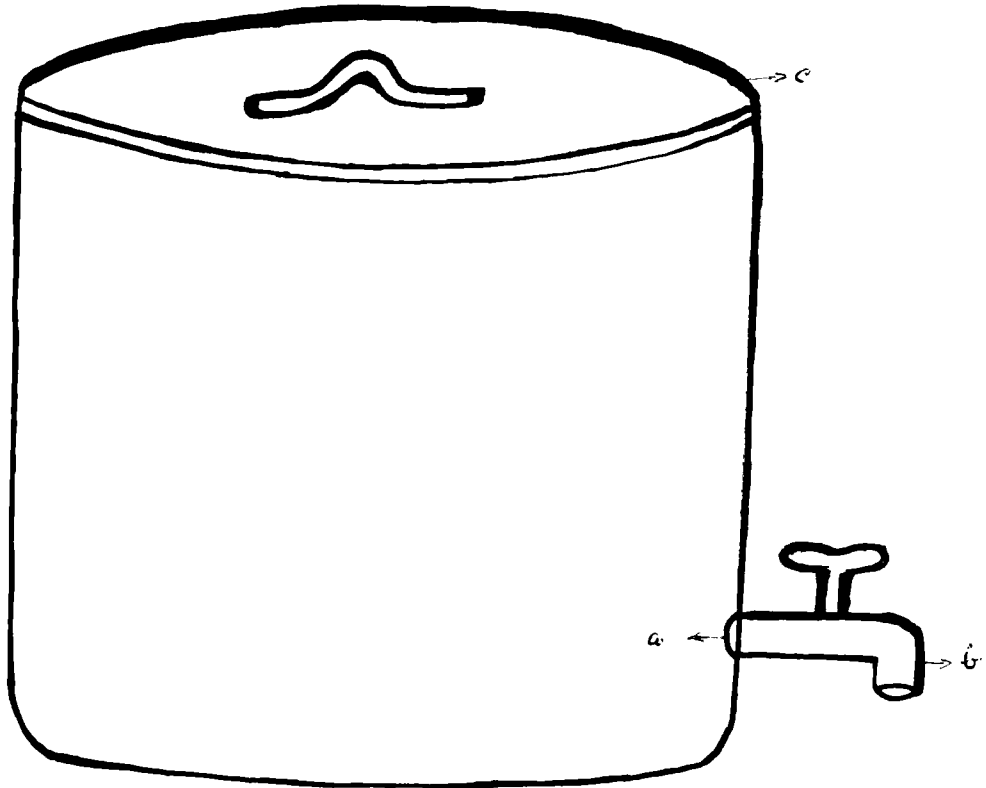


Figure 1

UTENSIL USED FOR PARBOILING

- a. Perforated circular plate
- b. Tap
- c. Lid.

The room temperature was noted every hour during the next six hours of soaking. The mean temperature was taken as the room temperature.

b. Hot soaking for three hours at 70°C - 75°C.

Six kilograms of paddy were weighed and put into eight litres of boiling water in the utensil shown in Figure 1. The temperature of the soaking water was maintained between 70°C - 75°C for three hours. Care was taken to soak the paddy completely and to maintain the water level at 2.5 centimeters above the paddy, for all the three hours. The utensil was kept open throughout the soaking period.

4. Parboiling the paddy

After six hours of soaking in the cold water at room temperature, the paddy was parboiled until the steam started coming out vigorously from the surface of the paddy, that is, one hour.

In the case of the paddy soaked at 70°C to 75°C for three hours, three litres of water were drained out before parboiling as there was excess water. The paddy was then parboiled until the steam came vigorously from the surface of the paddy, that is, in half an hour.

5. Drying the paddy

In the case of both the cold and hot water soaked paddy, one litre of water which was remaining after parboiling was drained out and the paddy was dried in the shade. Shade drying was selected because Govindaswami and Ghosh (1965) had concluded that shade drying was the best. The room temperature was noted at four hour intervals of drying and the average taken as the drying temperature. The moisture

content of 50 grams of all the samples was tested at 12 hours interval using the Universal Moisture Testing Apparatus with the help of the Seed Testing Laboratory in the State Agriculture College and Research Institute. Moisture was tested till the paddy reached approximately x 14 per cent level, as this amount of moisture was found by Jai Pal Singh and Dharma Rao (1966) to give good head rice return.

6. Dehusking the paddy

Handpounding and milling were selected as the dehusking processes. The handpounding was done using the traditional wooden mortar and pestle. Milling was done in the mechanical mill. Only one polishing was given to the paddy to minimise the nutritive losses due to polishing.

7. Cleaning the rice

The handpounded and milled samples of rice were winnowed by using hand winnower and the broken rice and husk were removed to retain the head rice alone. The samples were stored in bottles, labelled and used for nutrient analysis.

These processes were repeated six times, and the mean results calculated.

B. Nutrient Analysis of the Differently Processed Parboiled Rice

1. Calories

The caloric content of the sample of rice was analysed using the Parr's Oxygen Bomb Calorimeter (1960). The method is given in Appendix J

2. Protein

The protein content of the samples of rice was estimated by the Microkjeldahl method as described by the A.O.A.C. (1960), using the conversion factor 5.95 for the calculation of protein. Since, isolated rice protein contains 16.8 per cent nitrogen, the factor of 5.95 has been recommended for conversion of the nitrogen content of rice to protein (Harris and Loesecke 1960).

3. Phosphorous

The phosphorous content was determined by the Fiske and Subba Rao's method (1954).

4. Iron

Iron was estimated by using the method of Wong as described by Hawk et al (1954).

5. Thiamine

For the estimation of thiamine, the thiochrome method was used as described by A.O.A.C. (1960) with modifications. The method is given in Appendix. II

IV. RESULTS AND DISCUSSION

Six rice samples were soaked for six hours at the room temperature and the other six soaked for three hours at 70°C and both were steamed subsequently. The parboiled paddy after drying was dehusked by handpounding or milling and the 24 samples were analysed in duplicates for the following nutrients:

- A. Calories
- B. Protein
- C. Phosphorus
- D. Iron
- and E. Thiamine.

1. Calories

The mean caloric content of the differently processed parboiled rice is presented in Table III. Statistical analysis and analysed mean values for calories are given in Appendix \bar{V} and \bar{X}, \bar{X}' respectively.

TABLE III
MEAN CALORIC CONTENT OF THE DIFFERENTLY PROCESSED
PARBOILED RICE

(Mean values of duplicates)

Code	Processing Method	Calories per g.	Source of variation	Variance Ratio(F)
1.	Hot soaked handpounded rice.	361 ± 1.2 ^a	1 vs 2	4.011
2.	Hot soaked milled rice	370 ± 2.2	1 vs 3 1 vs 4	0.043 0.0004
3.	Cold soaked handpounded rice.	360 ± 1.2	2 vs 3	4.8*
4.	Cold soaked milled rice	361 ± 3.4	2 vs 4 3 vs 4 1& 2 vs 3&4	3.739 0.072 2.294

*Significant at 5 per cent level.

a. Mean ± standard error

The difference in the caloric content of the handpounded samples of rice of the hot soaking process and those obtained by the cold soaking process was not significant. Similarly there is difference in the caloric content of the milled samples of rice after hot soaking and cold soaking, but ^{it} is not significant.

When the hot soaked rice samples and cold soaked rice samples in both processes combined ^{by} were compared, it was found that the difference in temperature and time used in the two processes, did not affect the caloric content of the rice samples and the difference was not significant.

2. Protein

Table IV gives the protein content of the differently processed parboiled rice. Statistical appraisal is given in Appendix IV. In Appendix ^{and IV} analysed mean values are given.

TABLE IV
MEAN PROTEIN CONTENT OF THE DIFFERENTLY PROCESSED
PARBOILED RICE

(Mean values of the duplicates)

Code	Processing method	Protein g.per 100g.	Source of variation	Variance Ratio(F)
1.	Hot soaked handpounded rice	9.4 ± 0.24 ^a	1 vs 2	26.59**
			1 vs 3	1.21
2.	Hot soaked milled rice	8.0 ± 0.24	1 vs 4	47.87**
			2 vs 3	16.45
3.	Cold soaked handpounded rice	9.1 ± 0.24	2 vs 4	3.10
			3 vs 4	33.86**
4.	Cold soaked milled rice	7.6 ± 0.23	1&2 vs 3&4	4.09*
			1&3 vs 2&4	60.18**

**Significant at 1 per cent level.

*Significant at 5 per cent level.

a. Mean ± standard error.

^{IV}
Table shows the protein content of the differently processed rice samples. There was not much difference in the protein content between the hot soaked handpounded and cold soaked handpounded rice samples. Milled samples of hot soaked and cold soaked rice samples did not show appreciable difference in their protein content.

In both the processes of parboiling, the handpounded samples of rice showed higher protein content, when compared with the corresponding milled rice samples. The differences were highly significant at one per cent level.

Several investigators have reported on the protein content of parboiled rice. As stated by Subrahmanyam et al (1933) parboiling effects the transformation of the nitrogen present in the germ into the endosperm of rice grain. The handpounded rice samples retained the protein better. Hence, these results are in agreement with the work of Ghose et al (1960) and Swaminathan and Bhagavan (1960).

Generally it was found that although hot soaking had advantageous effect over the cold soaking on the protein content of rice, still it is much less than the difference due to hand pounding over milling.

In view of these significant differences, it is concluded that handpounding effected better conservation of protein than a mere difference in soaking method.

3. Phosphorus

Table V gives the phosphorus content of the differently processed rice samples. Appendix VII gives the statistical analysis and analysed mean values are given in Appendix X and XI



TABLE V

MEAN PHOSPHORUS CONTENT OF THE DIFFERENTLY PROCESSED PARBOILED RICE

(Mean values of the duplicates)

Code	Processing Method	Phosphorus mg. per 100g.	Source of variation	Variance Ratio (F)
1.	Hot soaked handpounded rice	174 \pm 1.7 ^a	1 vs 2	48.62**
			1 vs 3	2.29
2.	Hot soaked milled rice	131 \pm 2.3	1 vs 4	10.60**
			2 vs 3	72.11**
3.	Cold soaked handpounded rice	183 \pm 0.9	2 vs 4	13.81**
4.	Cold soaked milled rice	154 \pm 1.9	3 vs 4	22.80**
			1&2 vs 3&4	13.71**
			1&3 vs 2&4	69.01**

** Significant at 1 per cent level

There was no difference between the handpounded samples of cold and hot soaked parboiled rice in its phosphorus content. But there was significant difference in the phosphorus content between the milled samples of cold and hot soaked rice, as cold soaking had beneficial effect upon the phosphorus content of the rice. This may be due to more abrasion during milling.

The phosphorus content appears to have been affected by the processes used for dehusking the parboiled paddy, the handpounded samples of both the hot soaked and cold soaked parboiled rice having conserved the phosphorus in higher amounts than the corresponding milled samples. This finding is in agreement with those

of Swaminathan and Bhagavan(1960) and Joseph et al (1958) who reported that undermilling or handpounding increased the phytin phosphorus content of rice. Prem (1967) also obtains similar results.

1 Cold soaked parboiled rice and hot soaked parboiled rice were compared for the phosphorus content and it is evident that the cold soaked parboiled samples of rice had higher phosphorus content, and the difference between these two for the phosphorus content was significant at one per cent level. The increase in the phosphorus content of the cold soaked samples may be due to diffusion of the mineral from the outer bran layers and germ enriched with this nutrient, during the long hours of soaking period in the above process. The retention of phosphorus due to handpounding was even better than the retention in different soaking methods.

4. Iron

The differently processed rice samples were analysed for their iron content, and the values are presented in Table VI. Statistical appraisal and analysed mean values are given in Appendix $\overline{Y_i}$ and $\overline{X_i}$ respectively.

TABLE VI

MEAN IRON CONTENT OF THE DIFFERENTLY PROCESSED PARBOILED RICE

(Mean values of the duplicates)

Code	Processing method	Iron mg. per 100g.	Source of variation	Variance Ratio (F)
1.	Hot soaked handpounded rice	4.08 ± 0.13 ^a	1 vs 2	134.0**
			1 vs 3	61.08**
2.	Hot soaked milled rice	3.50 ± 0.09	1 vs 4	13.85**
3.	Cold soaked handpounded rice	6.25 ± 0.09	2 vs 3	48.22**
			2 vs 4	54.53**
4.	Cold soaked milled rice	4.65 ± 0.09	3 vs 4	105.7**
			1&2 vs 3&4	229.0**

**Significant at 1 per cent level.

a. Mean ± standard error.

It is evident that cold soaking had beneficial effect upon the iron content of the handpounded and milled rice samples, when compared with the corresponding hot soaked rice samples (treated similarly). The differences were significant at one per cent level.

Handpounding of the cold and hot soaked rice conserved higher amounts of iron than the corresponding milled samples, and the differences between the handpounded and milled samples of the hot and cold soaked parboiled rice were highly significant. The higher iron content of the handpounded rice may either be due to the partial presence of the bran in tact with the endosperm or due to the iron ring of the pestle

which is used for handpounding. This view is in agreement with the results of Swaminathan and Bhagavan (1960), Aykroyd et al (1966), and Prema (1967).

Cold soaked parboiled rice was compared with hot soaked parboiled rice, and it was found that the long hours of cold soaking had beneficial effect upon the iron content of the respective samples of rice, and the difference, in iron content on comparison with hot soaked parboiled rice was highly significant.

Thus, it is evident that the processes, cold soaking and handpounding resulted in the conservation of iron in the rice samples.

5. Thiamine

Rice is an important source of thiamine in Indian diets. Thiamine content of the differently processed parboiled rice samples was compared, and the values are given in Table VII. Appendix gives the statistical analysis and analysed mean values are given in Appendix

TABLE VII

MEAN THIAMINE CONTENT OF THE DIFFERENTLY PROCESSED PARBOILED RICE
(Mean values of the duplicates)

Code	Processing method	Thiamine ug.per 100g.	Source of variation	Variance Ratio (F)
1.	Hot soaked handpounded rice.	103 ± 0.004^a	1 vs 2 1 vs 3	1443** 2
2.	Hot soaked milled rice	54 ± 0.001	1 vs 4 2 vs 3	200.9** 111.8**
3.	Cold soaked handpounded rice.	97 ± 0.003	2 vs 4 3 vs 4	4.6* 162.4**
4.	Cold soaked milled rice	45 ± 0.014	1&2 vs 3&4 1&3 vs 2&4	6.5** 7.6**

**Significant at 1 per cent level

*Significant at 5 per cent level

a. Mean \pm standard error.

It could be seen that there was not much difference in the thiamine content between the hot soaked and cold soaked handpounded rice samples although the former had a slightly higher content. The difference was significant at 5 per cent level in the case of hot soaked and cold soaked milled rice samples.

Between the two processes used for dehusking, namely milling and handpounding in both the cases of hot soaking and cold soaking, handpounding had beneficial effect upon the thiamine content, and the differences were highly significant. Rama Sastri (1967) states that the handpounded rice is richer in B-vitamins because of the partial removal of the germ and bran. But the absorbability of the B-vitamin in the milled ^{under condition} contents has been questioned by Sreenivasan (1966).

Sarby and Tonius (1960) studied the effects of duration of parboiling on the thiamine content of rice. They noted a decrease in the thiamine content with increase in the time of soaking. Nicholls (1960) reported that a loss of 30 per cent of thiamine during the parboiling process may occur due to oxidation. So also in the present study, decreased values in thiamine content were obtained for the cold soaked rice samples, which were submitted to longer soaking time, being six hours, when compared with the hot soaked rice samples which were soaked only for three hours. This difference was also highly significant, between the two differently soaked rice samples.

V. SUMMARY AND CONCLUSION

1. Paddy was parboiled by two different methods of soaking, the cold soaking for six hours and the hot soaking for three hours followed by steaming. The difference in the nutrient contents of rice observed ^{tain} from these two processes was studied in respect of calories, protein, phosphorus, iron and thiamine. The difference was further studied with respect to handpounding and milling of the parboiled paddy.

2. The calorie content of parboiled rice ranged from 361 to 370. Differences were not marked either with respect to the method of soaking in parboiling or the method of dehusking.

3. The protein, phosphorus, iron and thiamine content of parboiled rice ranged from 7.6 to 9.4 g. 131 to 183 mg, 3.5 to 6.25 mg. and 45 to 103 ug per 100g. respectively. The lower values in respect of phosphorus and thiamine content than those reported in literature may be due to the variety difference in rice.

4. Generally the effect of handpounding as against milling on the retention of protein, phosphorus and thiamine was significantly ^{milled} beneficial, than that of the cold soaking against hot soaking. In iron content, however, both handpounding and cold soaking had effected better retention. The beneficial effect on

the retention of nutrients of the cold soaking process was not consistent because the thiamine tended to decrease in the cold soaking process as against hot soaking.

5. Rice is a poor source of protein but through parboiling and handpounding, significant retention of the protein can be effected so that the quantity of protein consumed through this source in the South Indian diet can make a significant contribution. Thiamine can also be conserved through parboiling and handpounding.

BIBLIOGRAPHY

- Ahmed, B., Dutt T.R. and Narang, D.
1945. Studies on calcium and phosphorus metabolism.
Part I.
Indian Journal of Medical Research, 33, 102.
- Aykroyd, W.R.
1964. Enough to eat. Food for Man.
Macmillan Book Co,
- Aykroyd, W.R.
1966. The Nutritive Value of Indian foods and the planning of
satisfactory diets. Special Report Series No.42,
Indian Council of Medical Research, New Delhi.
- Aykroyd, W.R., Krishnan, B.G., Pasamore, R. and Sundararajan, A.R.
1940. The Rice Problem in India.
Indian Journal of Medical Research, Memories No.32, 15.
- A.O.A.C.
1960. Thiochrome method.
Official Methods of Analysis. Washington D.C.,655.
- Bhattacharya, K-R.
1967. Conditions of drying parboiled paddy for optimum
milling quality. Journal of Food Science and Technology,
4., No.1, 19.
- Brown, D.D.
1966. Recent Trends in the milling and processing of rice.
Indian Farming Special Rice Number.
Indian Council of Agricultural Research, 16, No.6, 74.
- Bandopadhyay, B., and Ghose, T.K.
1965. Studies on the hydration of Indian paddy, Part I - A
rate equation for soaking operation.
Indian Journal of Technology,3, 360.
- Block, R.J. and Bolling, D.
1951. The amino acid composition of proteins and food.
The Spring - Field, Illinois, Charles C. Thomas.
- Basu, K.P. and Basak, M.J.
1937. Biochemical investigations of different varieties of
Bengal rice, Part IV. Biological value of proteins of
Aman and Ans. rice and of their polishings.
Indian Journal of Medical Research, 24, 1943.

- Brown, D.D.
1965. Rice Industry in India. Increasing milling out turn of rice. *Journal of Food Science and Technology*, 2, Nos.3-4,88.
- Central Food Technological Research Institute,
1956. "Parboiling of paddy". Project Circular-1
Simpson, J.E., Adair, C.R., Kohler, G.O., Dawson, E.R., Deobald, H.J., Kester, E.P., Hogan, J.T., Batcher, D.M., and Malck, V.J.
Quality Evaluation studies on Foreign and Domestic Rices. Technical Bulletin, No.1331, U.S. Department of Agriculture.
- Central Food Technological Research Institute, Mysore. Project Circular No.7 (revised),
Parboiling of Paddy.
- Charles, E.D.
1930 Treatment and prospects of rice in British Guiana. Paddy Miscellaneous Publications, London.
- Cousins, N.
1964. Rice - Hope and the International Rice Research Institute. Food and Farming. Industrial and Trade Publications, Private Ltd., New Delhi, No.7.
- Central Food Technological Research Institute.
Rice
Some facts about rice.
- Davidson, S. and Passmore, R.
1966. Rice
Human Nutrition and Dietetics, Third ed.
E. & S. Livingstone Ltd,
Edinburgh and London.
- Deodhar, K.V. and Dandekar, G.G.,
1965. Handpounding and Machine milling of paddy.
Journal of Food Science and Technology.
- Desikachar, H.S.R. and Subramanyan, V.
1957. The curing of freshly harvested paddy Part I, Industrial.
The Journal of Scientific Industrial Research, 16, . 365.
- Douglas, C.E.
1950. Report on the cultivation treatment and prospects of rice in British Guiana.
Printed and Published by His Majesty's Stationary Office,
London.

- Desikachar, M.S.R., Sankaran, S., and Subrahmanyam, V.
1956. The comparative nutritive value of soyabean and bengal gram as supplements to the poor South Indian rice diet. Indian Journal of Medical Research, 44., 741.
- Doris, D.B.
1966. Recent trends in the milling and processing of rice. Indian Farming. Special Rice Number. Indian Council of Agriculture Research, New Delhi, 16, No.6, 74.
- Desikachar, H.S.R., Lakshminarayan, S.K. and Subrahmanyam, V.
1957. Improvements in parboiling of paddy. Research and Industry 2., 151.
- Desikachar, H.S.R. and Subrahmanyam.
1957. The curing of freshly harvested paddy, Part I. Journal of Scientific Industrial Research, 1957 16, 365.
- Done, J.
1949. The effect of various treatments of paddy rice on the aneurin and Nicotinic acid content of milled rice. British Journal of Medical Research, 3., 335.
- Food and Agriculture Organisation.
1954. Effect of processing and household preparation on nutritive value. Rice and Rice Diets - A Nutritional Survey, Rome, 10.
- Food and Agriculture Organisation.
1953. Preliminary Operations (Pre-processing) Equipment for the Processing of Rice. F.A.O. Development paper No.27, Agriculture, FAO, Rome.
- Food and Agriculture Organisation.
1966. Rice in the World Food Economy, 33.
- Fiske and Subba Rao's Method.
Haw, P.B., Oser, B.L., and Summerson, W.H.
1954. Practical Physiological Chemistry. 13th edition. McGraw-Hill Book Company, Inc, New York.

- Ghose, R.L.M., Ghatge, M.B. and Subrahmanyam, V.
1960. Some aspects of the technology of rice processing in India.
Rice in India - Indian Council of Agricultural Research, New Delhi. 383.
- Grist, D.H.
1954. Report on the marketing of rice in India.
Macmillan Book Company.
- Govindaswami, S., and Ghosh, A.K.
1965. Varietal differences in hulling and cooking qualities of rice. Journal of Agricultural Research, Indian Council of Agriculture Research, New Delhi.
- Giri K.V.
1940. Availability of calcium and phosphorus in cereals.
Indian Journal of Research, 28., 103.
- Govindaswami, S.
1966. Effect of pre and post-harvest conditions on milling.
Indian Farming Special Rice Number.
Indian Council of Agriculture Research, 16, No.6, 71.
- Gupta, A.P., Khadi Gramodyog.
1967. The Journal of Rural Economy.
Thirteenth year of publication, 13, 5, 363.
- Harris, R.S. and Loesecke, H.V.
1960. Composition of rice. Nutritional Evaluation of Food Processing.
John Wiley and Sons, Inc, Publishers.
- Hawk, P.B., Oser, B.L., and Summerson, W.H.
1954. Practical Physiological Chemistry.
Thirteenth Edition, McGraw-Hill Book Company, Inc,
New York.
- Hinton, J. J.C.
1948. Parboiling treatment of rice.
Nature., 192, 913.
- Hsu, F., and Kiang, L.
1948. Journal of Physiology, 16, 451.

- Hogan, J.T.
1965. Rice Research at the Southern and Western Utilisation Research and Development Division. Journal of Food Science and Technology, No.4, 98.
- Kuri en, P.R., Radhakrishnamurthy, R., Desikachar, H.S.R., and Subrahmanyan, V.
1964. Effect of parboiling on the swelling quality of rice. Cereal Chemistry, 51., No.4, 16.
- Indian Council of Agriculture Research.
1955. Rice in India
Rice cultivation in India.
Farm Bulletin, No.1, Farm Information Unit.
- Indian Council of Agricultural Research.
1960. Rice Newsletters. New Delhi.
- Joseph, K., Rao, M.N. Ganapathy, S., Swaminathan, M. and Subrahmanyan, V.
1958. Studies on the nutritive value of rice and rice diets. Part II - Metabolism of nitrogen, calcium and phosphorus in children on poor vegetarian diets, containing husked, unde milled, milled raw rice. Annals of Biochemistry Experimental Medicine, 18, 54.
- Jaipal Singh. and Dharma Rao, K.
1966. Storage and Milling of paddy. Bulletin of Grain Technology, 4., No.1, 25.
- Jackson, E.A.
1967. Tropical rice: The quest for higher yields. World Farming, 9., 14.
- Joachim, A.W.R., and Kandiah, S.
1929. The Chemical composition of some Ceylon paddies, rices, and Milling Products: Tropical Agriculture, 70, 195.
- Kent, J.D.W., and Amor, A.J.
1947 Modern Cereal Chemistry
The Northern Publishing Co, Liverpool, 3.
- Kuppuswamy, S., Giri, K.V., and Subrahmanyan, V.
1949. Supplementary value of oil seed cake to South Indian Diets India Journal of Medical Research, 37., 41.

- Kik, M.C.
1956. Journal of American Dietetic Association, 32, 647.
- Lugai, B. and Fance, G.
1963. Parboiled rice production and use. Rice Journal, vol.65, No.1, 1962, 32.
- Loren, L.D.
1950. California Agricultural Extension Service
University of California, Circular No.163, 27.
- Lucius, N.
1961. Tropical Nutrition and Dietetics.
Baltimore, Tindall and Cox, 195.
- Mamjundar, B.N. and De, N.K.
1938. Oxalic acid content of some Indian Foodstuffs.
Indian Journal of Medical Research, 25, 671.
- Mecham, D.K., Kester, E.B. and Pence, J.W.
1961 Parboiling characteristic of California medium grain.
Food Technology, 15, No.11, 475.
- Milton, E. Elley, H.H., and Stetatas, K.
1952. Elements of Food Engineering.
Rinehold Publication Corporation, New York
- Mitra, K., Verma, S.K.
1947. Biological value of proteins fed to human beings.
Indian Journal of Medical Research, 35, 23.
- Mitra, K., Verma, S.K., and Ahmed, S.
1948. Investigations on biological value of cereal mixtures
in rice eater's diet by human feeding trials.
Indian Journal of Medical Research, 36, 261.
- Miller, C.
1960. An Introduction to foods and Nutrition.
Macmillan Company, New York.
- Mason, E.D., Devadas, R.
1946. The effects on growth in rats of butter and ragi
(Elemsine Coracona) separately and combined as
supplement to the poor rice diet of South India.
Indian Journal of Medical Research, 34, 335.

- McCall, E.R. and Hoffpanir, C.L. and Skan, D.B.
1951. The Chemical Composition of Rice.
A Literature review, USDA, ARS.
- National Research Council of the United States of America.
1945. The Nutritional Improvement of white rice.
National Academy of Sciences, Washington, D.C. 21.
- Normand, F.L., Hogan, J.T., and Deobald, H.J.
1965. Cereal Chemistry, 42, No.4, 359.
- Normand, F.L., Soignet, D.M., Hogan, J.T. and Deobald, H.J.
1966. Content of Certain nutrients in high protein rice flour.
The Rice Journal, 3238.
- Nicholls, L.
1960. Tropical Nutrition and Dietetics.
Fourth edition, London, Bailliere Tindall and Cox, 197.
- Operational Data Rice.
1967. Technical Aids Division.
Office of Industrial Resources.
International Corporation Administration, Washington 25, D.C.
- Osee Hughes,
1958. Cereal grains most commonly used in the United States.
Introductory Foods. The Macmillan Company, Third edition.
- Parr Instrumental Company.
1960. Oxygen Bomb Calorimetry and Combustion Methods.
Technical Manual No.130, Illinois, 33.
- Pal, B.P.
1966. Rice Research a case for coordination. Indian Council
of Agriculture Research, Indian Farming Special/number /rice
New Delhi.5
- Patwardhan, V.N.
1961. Rice.Nutrition in India.
Indian Journal of Medical Sciences, Bombay-17.
- Parthasarathy, M.
1960. Rice cultivation in India.
Farm Bulletin, No.1. Farm Information Unit, Directorate
of Extension, Ministry of Food and Agriculture, New Delhi.1

- Parthasarathy, N.
1966. Trends in rice production and consumption in Far East. Indian Farming. 16., No.6, 14.
- Prema, C.B.
1967. Comparison of the Nutritive Value of an Improved Strain, of Rice, ADT 27 with that of a Local strain ASD 5. A Thesis submitted to the University of Madras in Partial fulfilment of the Requirements for the Degree of Master of Science.
- Prescott, M.C. and Proctor, B.E.
1957. Food Technology. McGraw-Hill Book Co, Inc, New York, 70.
- Pingale, Storage and Milling of paddy.
1966. Bulletin of Grain Technology. 4, No.1, 25.
- Randhava, M.S.
1960. Rice in India. Indian Council of Agriculture Research, New Delhi.
- Ramiah, K.
1937. Rice in Madras. A Popular Handbook Printed by the Superintendent, Government Press.
- Rama Sastri, B.V.
1967. Rice - The food of the millions. Nutrition. Indian Council of Medical Research, 1, 4, 12.
- Ramaiah, K.
1966. Rice Research and production in India. Indian Farming, Special Rice Number, New Delhi. Indian Council of Agriculture Research, 26., 6, 8.
- Revathi Balakrishnan.
1967. Standardisation of the household parboiling process of paddy. A Thesis submitted to the University of Madras in Partial Fulfilment of the Requirements for the Degree of Master of Science.
- Ramamurthy, P.S.V. and Gopalan, G.
1966. Studies on thiamine excretions on raw and parboiled rice diets in human subjects. Indian Journal of Medical Research, 54, 208.

- Sarin, L.L.
1966. Rice milling policy in India. Khadi Gramodyog. The Journal of Rural Economy, Twelfth year of publication, 12, 4, 290.
- Spring,
1966. A New day for man's oldest crop--Rice. IMC World. Rice - Mainstay and Hope for half the world, 7, No.1, 5.
- Simpson, I.A.
1961. The distribution of thiamine and riboflavin in rice grains, with a study of changes that occur in the distribution of thiamine during the process of par-boiling. Bulletin from Institute of Medical Research, Federation of Malaya: No.6, 4.
- Simpson, J.E. and Others:
1965 Quality evaluation or studies of foreign and domestic R rices. Technical Bulletin 1381, USDA, ARS, Washington D.C.
- Sontakay, K.R.
1966 Storage of Rice. Indian Farming. Special rice number, Indian Council of Agriculture Research. New Delhi, 145.
- Srinivasan, C.R.
1935. Report of the rice production and trade in Madras Presidency. ~~xxxx~~ The Madras presidently Govt. Press. -
- Sundararajan, A.R.
1938. ~~xxxx~~ Phytin phosphorus content of Indian Foodstuffs, Indian Journal of Medical Research, 25., 671.
- Swaminathan, M.
1937. The relative value of the proteins of ^{cereals} such foods in nutrition. Part II. The comparative biological values of the proteins of certain cereals, pulses and skimmed milk powder, measured by the growth of young rats. Indian Journal of Medical Research, 25, 671.
- Stanley, L. and Cline, J.A.
1950. Cereals and cereal food ~~relation~~. ~~xxxxxx~~ Foods - their ~~re~~lation and preparation. Revised edition. Ginn and Company, New York.

- Swaminathan, M. and Bhagavan, R.K.
1960. The Effect of milling, washing and cooking on the nutritive value of raw and parboiled rice. Our Food. Madras, Ganesh and Company.
- Sreenivasan, A.
1966. Feed - backs of nutrition research. Journal of Nutrition and Dietetics, 4, No.3, 1.
- Sarda, P.S.
1965. Improved method of parboiling in Sarda rice and oil Mills. Journal of Food Science and Technology, 2, Nos. 3-4, 105.
- Sadasivan, V. and Sreenivasan, A.
1938. Studies on quality of rice. Part II. Chemical composition of rice varieties. Indian journal of Agriculture Science. New Delhi.
- Subrahmanyam, V., Sreenivasan, A. and Das Gupta, H.P.
1938. Studies on Quality in rice. Indian Journal of Agriculture Science, 53, 459.
- Sarby, Z.I. and Tonnous, R.I.
1960. Effect of parboiling on the thiamine riboflavin niacin contents of wheat, Abstracts, Fifth International Congress on Nutrition, 12.
- Snedecor, G.W.
1961. Statistical Methods. Allied Pacific Private Ltd, Bombay, 244.
- Tetzu, C. and Elisco, A.B.
1965. The morphology of varietal character of the rice plant. The International Rice Research Institute, Technical Bulletin.
- Vijayan, K.K., Sahadwan, P.C. and Kellakutty, M.M.
1965. Preliminary study on husking raw and parboiled paddy Rice Newsletters., Indian Council of Agricultural Research, New Delhi, 22, No.3.
- Warnick, K.P., Lachringer, M.V., Bring, S.V., and Woods, B.
1956. Physiological availability of thiamine from potatoes and from brown rice. Journal of Nutrition, 54, 121.
- William, R.R.
1959. Progress in cereal enrichment. Journal of the American Dietetic Association, No.27, 295.
- Yengnarayana Iyer, A.R.
1958. Field Crops of Indian with special reference to Mysore. Fifth edition. The Bangalore Printing and Publishing Co, Ltd,

APPENDICES

APPENDIX I

DETERMINATION OF ENERGY VALUE USING PARR'S OXYGEN BOMB CALORIMETER

Principle

The heat given off by the burning of a weighed sample of food is dissipated into a known weight of water in which the rise in temperature can be accurately measured. From the change in the temperature of the water, one can calculate the energy value of food.

Reagent needed

Standard alkali solution (0.0725N) sodium carbonate. This was prepared by dissolving 3.84 g. of sodium carbonate in water and diluting to one litre.

Procedure

Operating the Plain (Isothermal-Jacket) Calorimeter

Calorimeter Water

Determined the weight of completely dried oval bucket and then added 2000 (plus or minus 0.5) gms. of distilled or demineralised water.

Assembling the Calorimeter

The filled bucket was set in the jacket with a long axis of the oval in line with the operator and with the bomb locating boss in the bottom position nearest the operator.

The bomb, after setting the weighed powdered rice sample and electrodes in position, was filled with oxygen until the gauge read 20 atmosphere. The valve was closed and the bomb was lowered into

the water taking care to avoid jarring or disturbing the contents by holding the bomb valve between the thumb and forefinger. The bomb was set with its feet spanning the locating boss and turned so that the electrode terminal is near the insulated ignited wire. Attached the thrust terminal to the bomb electrode and shook back into the bucket all drops of water adhering to the fingers.

Placed the cover on the jacket with the thermometer towards the operator. Put on the rubber drive belt and started the motor. Always the same stirrer speed should be maintained.

Temperature operation

The motor was run for five minutes to attain thermal equilibrium. Then read and recorded the calorimeter temperature to the nearest 0.005°F (0.002°C) at one minute interval for exactly five minutes.

The firing was done at the start of the sixth minute recording the temperature. Then the temperature was recorded at 15 m seconds interval for five minutes.

After the period of rapid rise after firing, recorded the temperature to the nearest 0.005°F at one minute intervals until the difference between successive readings had been constant over a period of five minutes. Usually, the temperature will reach a maximum, then drop very slowly. So, the readings continued at one minute intervals over a period of five minutes.

Opening the Calorimeter

After completing the readings, the motor was stopped. Removed the belt and lifted the cover from the jacket. The thermometer was removed and wiped. Disconnected the firing connection from the bomb terminal and lifted the bucket and bomb out of the jacket.

Lifted the bomb out of the jacket and relieved all residual pressure. This should be done slowly and at a uniform rate such that the operation will require not less than one minute.

After all pressure had been relieved, removed the screw cap, lifted out the bomb head.

The Acid Titration

Washed all interior surfaces of the bomb with a jet of distilled water and quantitatively collected the washing in a beaker. Titrated with standard alkali (0.0725N) solution using methyl orange indicator.

The Fuse Correction

Carefully removed all unburnt pieces of fuse wire from the bomb electrodes, straighten them and measured their combined length in centimeters. Subtracted this length from the initial 11 centimeters and entered this value.

Calculations

Assembly of Data

The following data should be available at the completion of a test in the plain calorimeter.

- a - Time of firing.
- b - Time to nearest 0.1 minute when the temperature reaches 60 per cent of the total rise.
- c - Time at beginning of period after the temperature rise (in which the rate of temperature change has become constant).
- ta- Temperature at time of firing, corrected for thermometer scale error.
- tc- Temperature at time C, corrected for thermometer scale error.

- r_1 - rate (temperature units per minute) at which temperature was rising during the five minutes period before firing.
- r_2 - rate (temperature units per minute) at which the temperature was falling during the five minutes period after time C. If the temperature was rising instead of falling after time C, subtract the quantity $r_2 (c-b)$ instead of adding it when computing the corrected temperature rise.
- c_1 - millilitres of standard alkali solution used in the acid titration.
- c_2 - centimeters of fuse wire consumed in firing.
- w - energy equivalent of the calorimeter in calories per degree of F.
- m - mass of the sample.

Temperature Rise

Computed the net corrected temperature, t , by substituting in the following equation:

$$t = t_c - t_a - r_1 (b-a) - r_2 (c-b)$$

Thermochemical Correction

Computed the following for each test:

- l_1 - correction in calories for heat of formation of HNO_3 - C1 if 0.0725N alkali was used for the titration.
- l_2 - correction in calories for heat of combustion of fuse wire - (2.3) (c_2) when using Parr 45 C₁₀ nickel wire.

Gross Heat of Combustion:

Computed the gross heat of combustion H_g in calories per gram by substituting the following equation:

$$H_g = \frac{tw - l_1 - l_2}{m}$$

APPENDIX I

ESTIMATION OF THIAMINE BY THIOCHROME METHOD

Principle;

Thiochrome procedures depend upon the oxidation of thiamine to thiochrome which fluoresces in ultra-violet light under standard conditions and in the absence of the other fluorescing substances, the fluorescence is proportional to the thiochrome present and hence to the thiamine originally in solution.

Reagents needed

1. Double normal sodium acetate
2. Bromocresol green pH indicator
3. Basic lead acetate solution
4. 15 per cent sodium hydroxide
5. 1 per cent potassium ferricyanide solution
6. Oxidising reagent
7. Quinine sulphate stock solution (10 μg per ml).
8. Quinine sulphate standard solution (0.25 μg per ml).
9. Thiamine hydrochloride stock solution I (100 μg per ml).
10. Thiamine hydrochloride stock solution II (10 μg . per ml).
11. Thiamine hydrochloride standard solution (1 μg . per ml).
12. n - Butanol
13. Potassium chloride.

Preparation of reagents:

1. Double normal sodium acetate: Dissolved about 275 g. of sodium acetate in sufficient water to make up to 1000ml.
2. Bromo cresol green pH indicator: Dissolved 0.1 g. of the indicator by triturating in agate mortar with 2.8 ml. of 0.05N sodium hydroxide, then diluted to volume of 200 ml. with water.
3. Basic lead acetate solution: Dissolved about 180 g. of lead acetate in 700 ml. of nearly boiling distilled water and added 110 g. of finely powdered lead oxide (litharge). Boiled the mixture for half an hour with occasional stirring, cooled the solution, filtered and added sufficient water to the filtrate to make 1 litre.
4. 15% Sodium hydroxide solution: Dissolved about 110 g. of sodium hydroxide in 100 ml. of distilled water, and allowed the saturated solution to stand for about 2 days, so that the carbonate settles down. This solution contains about 75g. of sodium hydroxide in 100 ml. This is diluted to 500 ml. with distilled water to get 15% solution.
5. 1% Potassium ferricyanide solution: Dissolved 1g. of potassium ferricyanide in 100 ml. of distilled water, and it is prepared freshly.
6. Oxidising reagent: Mixed 4.0 ml. of the 1% potassium ferricyanide solution with the 15% sodium hydroxide solution to make 100 ml. This solution should be used within 4 hours.

7. Quinine sulphate stock solution: Dissolved about 10 mg. g Quinine sulphate in 1000 ml of 0.1N sulphuric acid, and stored it in light resistant bottles (10 ug/ml)
8. Quinine sulphate standard solution: Mixed 1 volume of the quinine sulphate stock solution with 39 volumes of 0.1N H₂SO₄ (0.25 ug/ml).
9. Thiamine hydrochloride stock solution I: Dissolved 50 mg USP thiamine hydrochloride Reference Standard in 20% alcohol adjusted to pH 3.5 - 4.3 with hydrochloric acid and diluted to 50 ml. with acidified alcohol to make concentration exactly 100m. ug/ml and stored at 10°C in light resistant bottles (100 ug/ml).
10. Thiamine hydrochloride stock solution II: Diluted 100 ml. of thiamine hydrochloride stock solution to 1 litre with 20% alcohol, adjusted pH to 3.5-4.3 with hydrochloric acid. Stored in light resistant bottles (10 ug/ml).
11. Thiamine hydrochloride standard solutions: To 10 ml. of thiamine hydrochloride Stock Solution II added ~~up~~ /100 ml. of 0.1N hydrochloric acid, (1 mg equivalent to 1 m. mg. of thiamine hydrochloride ~~acid~~ (1 u/ml).

Procedure

Extraction

Weighed about 10 gm. of ice finely powdered and dissolved in 50 ml. of 0.1N hydrochloric acid. It was digested over a boiling water bath for about half an hour at 95 to 100°C. Cooled and agitated to avoid lumping and diluted with 0.1N hydrochloric acid to 70 ml. Duplicates were prepared.

Enzyme hydrolysis

Aliquot of 20 ml. was taken in two beakers from the 70 ml. and adjusted to the pH to 4.0 to 4.5 with five ml. of double normal sodium acetate, using bromocresol green indicator on spot plate. Added five ml. of takadia isatase-enzyme solution, mixed and incubated for about three hours at 45 to 50°C and cooled to the room temperature.

Purification

After incubation, 10 ml. of basic lead acetate to each assay solution in the beaker, mixed well and the precipitate formed was removed by centrifugation. To the filtrate added 4 ml. of 30 per cent sulphuric acid followed by 4 ml. of distilled water to remove the excess lead by precipitating it. Again it was centrifuged and tested for the presence of lead by adding a drop or two drops of 30 per cent sulphuric acid. No precipitate should be seen at the end. The final volume was measured.

OXIDATION OF THIAMINE TO THIOCHROME AND MEASUREMENT OF FLUORESCENCE:

To the assay solutions and standard thiamine hydrochloride solutions, sufficient potassium chloride (1.5gm) was added. Then within two seconds added three ml. of oxidising reagent. Immediately added 13 ml. of n-Butanol and shaken vigorously. Centrifuged the solutions at low speed about one to three minutes. The clear solution at the top was taken and measured the fluorescence in electronic flurometer. The fluorescence produced by 10 ml. of the oxidised

thiamine hydrochloride standard was read. The fluorescence of n-Butanol was also read. Quinine sulphate standard solution is used to govern the reproducibility of the instrument and this is first adjusted to 100. For every sample and standard a blank should be prepared which is treated similarly as the assay solution except instead of oxidising agent 15 per cent sodium hydroxide is used.

Precautions

1. The completion of the removal of excess lead should be tested by allowing the precipitate to settle and adding cautiously a drop or two of the 30 per cent sulphuric acid.
2. In the case of rice, a reddish colour sometimes may appear in the extract either after making it alkaline or on the subsequent addition of potassium ferriocyanide solution.
3. If the solution is cloudy, shake it with 2gm. of anhydrous sodium bisulphate and centrifuge again.
4. The fluorescence of n-Butanol should not exceed 10 per cent of the fluorescence produced by quinine sulphate standard solution.

Calculation

$$\text{Thiamine content} = \frac{A \times X \times V_2 \times 100 \times v_4}{B \times V_1 \times W \times V_3} = \text{ug of thiamine per 100g.}$$

- A - Reading of the unknown
- B - Reading of the standard
- X - Concentration of the standard
- V₁ - Volume taken for incubation
- V₂ - Volume made up after digestion
- V₃ - Volume of the solution taken for oxidation step.
- V₄ - Volume of the total filtrate after purification
- W - Weight of the rice sample taken.

APPENDIX

CALCULATIONS FOR STANDARD ERROR
(for calories)

This sample standard error is symbolised $S\bar{x}$ and it is equal to $\frac{S}{\sqrt{n}}$ where 'S' is standard deviation of the mean 'n' is the number of observations standard error was calculated as follows:

$$\text{Standard error} = S\bar{x} = \frac{S}{\sqrt{n}}$$

$$S = \frac{\sum x_1^2 - (\sum x_1)^2/n}{(n-1)}$$

Where $n = 6$

$$\bar{x} = \frac{\sum x_1}{n} = \frac{2163}{6} = 360.5$$

$$(\sum x_1)^2 = 4678569$$

$$\sum x_1^2 = 780215$$

Using the above formula

$$S^2 = \frac{780215 - \frac{4678569}{6}}{(6-1)}$$

$$S^2 = 90.7$$

$$S = 9.52$$

$$\sqrt{n} = 2.449$$

$$S/\sqrt{n} = 3.88$$

For example

S.No.	x_1	x_1^2
1	348	121104
2	363	131769
3.	375	140625
4.	355	126025
5.	356	126736
6.	366	133956
Total 2163		780215

APPENDIX IV

ANALYSIS OF VARIANCE AND NON ORTHOGONAL COMPARISONS.

Any observed value is the sum of two parts.

- i) an over-all mean .
- ii) a treatment deviation and
- iii) a random element from a normally distributed population with mean zero and a standard deviation.

The following table shows a symbolic table of data for p groups with 'n' data in each group.

	Group-1	Group-2	Group-3
	x_1	y_1	p_1
	x_2	y_2	p_2
	n items	n items	n items
sums	X_1	Y_1	P_1

Total number of data $pn = N$

The calculations and analysis of variance are shown in the following Table.

Variation due to	Degree of Freedom	Sum of squares	Mean squares	Variance ratio (F)
Total	$N - 1$	(4)	-	-
Among means	$P - 1$	(5)	(7)	(9)
Within groups	$N - P = p((n-1))$	(6)	(8)	-
1. Sum of all data	$Sx = x_1 + xy_1$	-----		$p_1 = S$
2. Sum of squares	$Sx^2 = x_1^2 + xy_1^2$	-----		p^2

3. Correction term $C = S^2/N$
4. Total sum of squares $= \sum x^2 - C$
5. Among means $= x_1^2 + xy_1^2 - - - - - P_1^2/n-c$
6. Within groups $= \text{Line 4} - \text{line 5}$
7. Among means of mean square $= \text{Line 5}/p - 1)$
8. Within groups $= \text{Line 6}/N-p$
9. Items 7/2 Item 8.

The analysis of variance and non orthogonal comparisons among the means were done according to model 1 (Snedecor, 1956).

S.No.	Group 1		Group 2		Group 3		Group 4	
	x_i	x_i^2	x_i	x_i^2	x_i	x_i^2	x_i	x_i^2
1.	348	121104	370	136900	351	123201	376	141376
2.	363	131769	361	130321	369	136161	361	130321
3.	375	140625	369	136161	355	126025	359	128881
4.	355	126025	374	139876	348	121104	358	128164
5.	356	126736	373	139129	371	137641	361	130321
6.	366	133956	374	139876	363	131769	350	122500
Total	2163	780215	2221	822263	2157	775901	2165	781563

Group 1	$\sum x_i$	2163	$\sum x_i^2$	780215	$(\sum x_i)^2$	4678569
Group 2	$\sum x_i$	2221	$\sum x_i^2$	822263	$(\sum x_i)^2$	4932841
Group 3	$\sum x_i$	2157	$\sum x_i^2$	775901	$(\sum x_i)^2$	452649
Group 4	$\sum x_i$	2165	$\sum x_i^2$	781563	$(\sum x_i)^2$	4687225
$\sum x_i$		<u>8706</u>	$\sum x_i^2$	<u>3159942</u>	$(\sum x_i)^2$	<u>18951234</u>

NOTE:

- Group 1 - Hot soaked handpounded rice.
- Group 2 - Hot soaked milled rice.
- Group 3 - Cold soaked handpounded rice.
- Group 4 - Cold soaked milled rice.

APPENDIX V

TABLE FOR ANALYSIS OF VARIANCE FOR CALORIES

Source of variation	Degrees of freedom	sum of squares	Mean square	Variance Ratio (F)
Total	23	8942	-	-
Treatment	3	7547	2515.6	36.0**
Error	20	1395	69.8	-
1 vs 2	1	280	280.0	4.011
1 vs 3	1	3	3.0	0.043
1 vs 4	1	0.3	0.3	0.0004
2 vs 3	1	341	341.0	4.8*
2 vs 4	1	261	261.0	3.739
3 vs 4	1	5	5.0	0.072
1 and 2 vs 3 and 4	2	320	160.0	2.294

** Significant at 1 per cent level.

* Significant at 5 per cent level.

$$\begin{aligned} \sum x_i &= 8760 & \sum x_i^2 &= 3159942 & (\sum x_i)^2 &= 18951284 \\ x &= \frac{(8706)^2}{24} & \text{Treatment} &= y - x = 3158547 - 3151000 \\ y &= \frac{18951284}{6} \\ z &= 3159942 \end{aligned}$$

$$\begin{aligned} 1 \text{ vs } 2 &= 2221 - 2163 = \frac{(58)^2}{12} = \frac{3364}{12} = 280.3 \\ 1 \text{ vs } 3 &= 2163 - 2157 = \frac{(6)^2}{12} = \frac{36}{12} = 3.0 \end{aligned}$$

$$1 \text{ vs } 4 = 2165 - 2163 = \frac{(2)^2}{12} = \frac{4}{12} = 0.3$$

$$2 \text{ vs } 3 = 2221 - 2157 = \frac{(64)^2}{12} = \frac{4096}{12} = 341.3$$

$$2 \text{ vs } 4 = 2221 - 2165 = \frac{(56)^2}{12} = \frac{3136}{12} = 261.3$$

$$3 \text{ vs } 4 = 2165 - 2157 = \frac{(8)^2}{12} = \frac{64}{12} = 5.3$$

$$1 \text{ and } 2 \text{ vs } 3 \text{ and } 4 = 4384 - 4322 = \frac{(62)^2}{12} = \frac{3844}{12} = 320.3$$

Among the resultant 'F' values with n-1 degrees of freedom using the 't' tables only with those with a probability 0.05 to 0.01 or less were considered to be significant.

Based on the example given other calculations for analysis of variance and non orthogonal comparisons were done.

APPENDIX VI

TABLE FOR ANALYSIS OF VARIANCE FOR PROTEIN

Source of variation	Degree of freedom	Sum of square
Total	23	16.12
Treatment	3	12.33
Error	20	3.79
1 vs 2	1	5.04
1 vs 3	1	0.23
1 vs 4	1	9.03
2 vs 3	1	3.12
2 vs 4	1	0.59
3 vs 4	1	6.42
1 and 2 vs 3 and 4	2	1.56
1 and 3 vs 2 and 4	2	11.43

APPENDIX VII

TABLE FOR ANALYSIS OF VARIANCE FOR PHOSPHORUS

Source of variation	Degree of freedom	Sum of squares
Total	23	9902
Treatment	3	7637
Error	20	2265
1 vs 2	1	5504
1 vs 3	1	260
1 vs 4	1	1200
2 vs 3	1	8164
2 vs 4	1	1564
3 vs 4	1	2581
1 and 2 vs 2 and 4	2	3104
1 and 3 vs 2 and 4	2	15624

APPENDIX VIII

TABLE FOR ANALYSIS OF VARIANCE FOR IRON

Source of variation	Degree of freedom	Sum of squares
Total	23	25.64
Treatment	3	24.20
Error	20	1.44
1 vs 2	1	0.37
1 vs 3	1	4.41
1 vs 4	1	1.00
2 vs 3	1	3.49
2 vs 4	1	3.34
3 vs 4	1	7.65
1 and 2 vs 3 and 4	2	33.13

APPENDIX IX

TABLE FOR ANALYSIS OF VARIANCE FOR THIAMINE

Source of variation	Degree of freedom	Sum of squares
Total	23	0.0167
Treatment	3	0.0157
Error	20	0.0010
1 vs 2	1	0.0722
1 vs 3	1	0.0001
1 vs 4	1	0.0101
2 vs 3	1	0.0056
2 vs 4	1	0.0002
3 vs 4	1	0.0081
1 and 2 vs 3 and 4	2	0.0007
1 and 3 vs 2 and 4	2	0.0008

APPENDIX X

ANALYSED VALUES FOR CALORIES, PROTEIN, PHOSPHORUS, IRON AND THIAMINE
CONTENT OF THE HOT SOAKED PARBOILED RICE.

(Mean values represent values of duplicate determinations)

Particulars	Calories	Protein g.	Phosphorus mg.	Iron mg.	Thiamine mg.
Hot soaked - Hand pounded.					
1.	348	9.58	167	4.33	84
2.	363	9.23	178	3.94	101
3.	375	9.23	175	4.14	110
4.	355	9.39	176	3.82	106
5.	356	9.28	170	4.02	110
6.	366	9.28	177	4.20	108
Mean	361	9.33	174	4.08	103
Hot soaked - Milled					
1.	370	7.13	128	3.40	57
2.	361	8.67	130	3.37	57
3.	369	7.55	135	3.45	52
4.	374	8.28	133	3.63	54
5.	373	8.37	131	3.69	56
6.	374	8.21	129	3.50	48
Mean	370	8.03	131	3.50	54

APPENDIX XI

ANALYSED VALUES FOR CALORIES, PROTEIN, PHOSPHORUS, IRON AND THIAMINE
CONTENT OF THE COLD SOAKED PARBOILED RICE

(Mean values represent values of duplicate determinations)

Particulars	Calories	Protein g.	Phosphorus mg.	Iron mg.	Thiamine µg.
Cold soaked - handpounded:					
1.	351	9.49	185	6.12	97
2.	369	9.33	183	6.45	97
3.	355	8.56	181	6.18	97
4.	348	9.18	186	6.45	100
5.	371	8.98	180	5.22	109
6.	363	8.78	184	6.09	82
Mean	360	9.06	183	6.25	97
Cold soaked - milled:					
1.	376	7.10	152	4.70	47
2.	361	7.03	160	4.79	46
3.	359	7.79	148	4.45	42
4.	358	7.87	150	4.70	41
5.	361	7.87	158	4.61	50
6.	350	7.89	155	4.67	46
Mean	361	7.59	154	4.65	45