COMPARISON OF THE NUTRITIVE VALUE OF AN IMPROVED STRAIN OF RICE, ADT_{27} WITH THAT OF A LOCAL STRAIN, ASD_5

By

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I INTRODUCTION

Rice is Asia's staff of life. It is the key of survival for one third of humanity. Rice is cultivated in 200 million acres of land all over the world. Ninety per cent of this area are located in Asia. In 1963 - 1964, the world production of paddy was 154,305,000 tonnes*, 93 per cent of which came from Asia. India produced 34 million tons of rice in the year 1961 as estimated by the Indian Council of Medical Research (ICMR) (1964)[1].

Because rice means 'Life' to a large section of the world's population, the Food and Agricultural Organisation of the United Nations, (FAO)[2] has rightly designated the year 1966, as the "International Rice Year" (IRY). The major objective of the IRY is to give a better chance in life for the often impoverished 1,100 million people for whom rice is the basic food. Twenty three countries including India are participating in the 'International Rice Year' through activities such as, distributing improved seeds, expanding the use of fertilisers and working on better water management and mechanisation.

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* 1 metric tonne = 1000 kg. or .9842 ton.

The number of persons consuming rice in India is on the increase. According to the Indian Council of Agricultural Research, (ICAR) (1960)[3], in certain parts of the country, people who were accustomed to grains other than rice are also changing over to rice, because of its attractive colour, taste, shape, capacity for filling and giving satisfaction and prestige. In Madras State, the per capita consumption of cereal is high, with 383 g. of rice and 140 g. millets, while the intake of other food stuffs is low. The amount of cereals present in the average diet is 47 per cent more than the requirement (1964)[4].

Rice is consumed as 'raw' and 'parboiled'*, both of which may be 'husked'**, 'home-pounded'+ or milled++ to varying degrees. In Assam, West Bengal, Bihar, Orissa, the coastal regions of Bombay and the West coast, parboiled milled rice is preferred by the poorer classes of people (1954)[5]. The use of raw rice is limited to the coastal area of the Bay of Bengal, specially in Andhra

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* Parboiled rice has been defined as the rice obtained from paddy which has been steeped in water, steamed and subsequently dried, by pounding or milling.

** Husked rice is defined as 'brown rice', which is rice with the husk removed in such a manner that the germ, pericarp and aleurone layers are in tact.

\+ Home pounded rice is rice prepared by using a household pounding apparatus. In this process the bran, germ, pericarp and aleurone layers are partially removed from the endosperm.

++ Milled rice is rice obtained by dehusking the rice in a power machinery, where husk, germ, pericarp are completely removed and it is polished.

Pradesh (1940)[6]. It was in those areas, that Aykroyd and Krishnan (1937)[7] and Raman (1940)[8] observed the frequent occurrences of the deficiency disease beri beri among those who consumed highly milled raw rice.

The preference for milled rice in the place of home-pounded rice is based on attractiveness, ease in buying as it is available readily in the markets and low cost (Mrak and Stewart) (1948)[9]. However as Ghose et al (1960)[3] point out unmilled rice is superior in that it contains greater amounts of protein, calcium, phosphorous, iron, thiamine, and niacin. Milled rice contains 17 per cent less protein than husked rice and also less fat. Thiamine, riboflavin and niacin losses are also greater in milled rice regardless of the type of processing (1954)[5]. Therefore several workers (1940)[10], (1960)[11] have advocated the use of home-pounded or unmilled rice in the place of the highly milled rice. Promotion of the use of unmilled rice was one of the items of constructive work suggested by Mahatma Gandhi (1948)[12], (1965)[13]. The Village and Cottage Industries Commission is still pursuing this objective.

As far the nutrient content of rice processed by the different methods, the studies of Swaminathan and Bhagavan (1960)[11] and Ramamurthy and Gopalan (1966)[14] have proved that parboiled and dehusked rice contain the highest amounts of minerals and vitamins. The National

Research Council of the U.S.A.(NRC) (1945)[15] has also shown that parboiled rice is better than raw rice because of its greater contents of thiamine and niacin. The FAO (1954)[5] has computed that parboiled rice contains two to four times as much thiamine as milled raw rice.

Washing and cooking of rice lead to notable losses in nutrients. Swaminathan (1941)[16] reported that the loss of nicotinic acid during washing and cooking was greater in raw milled rice than in parboiled rice. Swaminathan (1942)[17], Miller (1945)[18], Kik and Williams (1945)[15] and Vinacke (1951)[19] demonstrated that the loss of thiamine was greater when raw rice was washed and cooked than when parboiled and brown rices underwent similar treatment. According to the FAO (1954)[5], husked rice gets less impoverished by washing and cooking than home-pounded or milled rice.

Rice contains only six to nine per cent protein (1966)[20] and the proteins of rice are of good quality (1947)[21], (1948)[22] although deficient in the amino acids, lysine and methionine. Rice is deficient also in calcium, iron, the fat soluble vitamins and vitamin C (1945)[15]. Several investigators have reported on the beneficial results of supplementing rice diets with different nutrients. Aykroyd and Krishnan (1937)[23], Krishnamurthy and Subramanyan (1947)[24], and Kuppuswami et al (1949)[25] demonstrated the supplementary values of calcium, phosphorous and vitamins to rice diets. Kik (1940)[26] and Pecora and Hundley (1951)[27] found that when a combination of amino acids such as lysine and threonine were added to white rice, the quality of rice proteins was improved as evidenced by increased rate of growth in rats. Devadas and Sutton (1951)[28] observed significant improvement in growth of rats fed on a basal rice diets supplemented with defatted egg yolk.

Today, India faces an unprecedented food crisis in which shortage of rice is crucial. Attempts are being made to increase the availability of rice through evolving improved hybrid strains with desirable economic characteristics such as yield, quality, nutritive value and resistance against disease. Aduthurai 27 (ADT-27) is one such strain. It has already to its credit one of the highest yield in rice cultivation in the country with a record of 4731 kg of grain/hectacre* (1966)[29]. ADT-27 is a derivative of a cross between the Japonica variety, Norin-8 and the Indica variety, GEB-24. It needs a duration of only 105 days for maturation. The 'Kar'+ crop is sown during June to July. In the year 1966 alone, 3000 acres were cultivated in Madras State with ADT-27.

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* One hetchare = 2.471 acres
\+ 'Kar' season = From June to October

Since ADT-27 is a new strain and has vast potentials for increasing rice production, there is need to study its nutrient content after processing by different methods. The present investigation was therefore undertaken to compare the nutrient content of dehusked, hand-pounded and milled ADT-27, both raw and parboiled with the values obtained for the local strain, ASD-5, treated similarly. It is hoped that the findings of this study will give further impetus to production of ADT-27 in the country and its balanced consumption.

II REVIEW OF LITERATURE

Since the objective of this study is to compare the nutritive value of dehusked, hand pounded and milled samples of both raw and parboiled rice of a selected strain ADT - 27, with that of a local strain ASD$_5$, the available literature is reviewed under the following heads:

A. Consumption of rice in India.

B. Cultivation and production of rice.

C. Nutritive value of rice.

D. Deficiencies in rice diets.

E. Types of rice differently processed:

1. Raw and parboiled rice.
2. Dehusked, hand pounded and milled rice.

F. Efforts to improve the nutritive value of rice:

1. Hybridization.
2. Influence of fertilisers and environment on nutrient content.
3. Rice enrichment.
4. Parboiling or conversion.

G. Supplementing rice diets with minerals, vitamins and amino acids.

A. Consumption of Rice in India:

Results of the diet surveys which have been carried out by the ICMR (1961) (1964)[1] reveal that cereals constitute a major portion of the dietaries, in which, as Patwardhan (1965)[30] states, 70 - 80 per cent of the total calories are furnished by rice. Out of the average per capita income of 428 Rupees per annum, the Indian citizen spends a major proportion, nearly 60 - 80 per cent on food. Therefore his diet consists only of cereals and negligible quantities of other foods and it is lopsided because of the extremely high cereal content (Mitra) (1951)[31].

The per capita consumption of rice varies widely from place to place, from 314 lbs/year in West Bengal and Assam which are the highest rice consuming areas, 266 lbs/year in Madras State and 20 lbs/year in Madras State and 20 lbs/year in Punjab (1960)[3]. The FAO (1954)[5] has reported that the average Indian diets consist of 477 g. of rice with 120 g. of other cereals. The consumption of protective foods such as milk, vegetables, meat and fruits is little or nil. The Central Food Technological Research Institute states that there are considerable regional differences in the level and pattern of food and grain consumption (CFTRI) (1965)[32]. The Eastern, Central and Southern states favour the consumption of rice and millets, while in the North and North West, consumption of wheat is predominant. A combination of rice and millets such as ragi and jowar is preferred by the people of the South, while a combination of rice and wheat is desired by those in the North (ICMR) (1964)[33]. The people in the Northern part of India consume also larger quantities of pulses than those in the South (1951)[31]. The surveys of the ICMR (1953)[34], and Kurien (1960)[35] show that jowar, ragi, bajra and cholam are the different types of millets consumed in India.

Of the total amount of rice consumed in India, 60 per cent are of the parboiled type (1965)[32]. Thirty per cent of the population use home pounded rice and all the others use milled rice (1954)[5].

B. <u>Cultivation and Production of Rice:</u>

Rice is one of the oldest crops to be cultivated in India. Today the cultivation of rice occupies 21 per cent of the total cropped area, 30 per cent of the total area under food grains including pulses, and 39 per cent of the total area under cereals (1965)[32]. The rice crop requires high temperature, high humidity and abundant water during growing periods (Mudaliar) (1951)[36]. Therefore, its cultivation is concentrated along the river valleys, deltas and low lying coastal areas of Northern, Eastern and Southern India, within the latitude of 8 - 35°, in Andhra Pradesh, Assam, Bihar, Kerala, Madhya pradesh, Madras, Maharashtra, Mysore, Orissa and West Bengal ICAR (1961)[37], (1965)[32].

There are two main methods of rice cultivation: the dry and the wet. Mudaliar (1960)[38] states that in the dry system, rice is grown on dry soil like other cereals. In contrast the wet system requires the growing plant to stand in water all the time till the harvest. Besides these two principal systems of rice cultivation, Ghose et al (1960)[3] describe the 'Udu' type or mixed cultivation which consists of growing together two varieties with different durations. The other methods are the 'Podu' or shifting cultivation and the 'Japanese' method of cultivation. The former is in practice in the hilly areas of Kerala, Orissa, Assam and Andhra pradesh.

The sowing practices in regard to paddy are of three types: (1) broadcasting the seed (2) sowing the seed in furrows (3) drilling the seeds directly in to the field (FAO) (1966)[39]. Transplanting is done after germination of the seeds. Manuring, irrigation, weeding and interculturing are the important processes to be carried out in rice cultivation. When the crop is ripened, harvesting takes place followed by threshing Chaudry et al (1966)[40].

Fertilisers play a vital role in rice cultivation. CFTRI (1965)[32] states, that green manure effects appreciable increase in yields, upto 10 to 15 per cent more than that achieved by the application of other manures like compost soil and seed cake. High yields of grain have also been obtained through the use of nitrogen and phosphate fertilizers.

During the year 1962 - 1963, the total production of rice in Madras State was 3,876 tonnes whereas it was 3,855 tonnes in the following year 1963-1964 (1965)[32].

According to Ramiah (1966)[41], the past 15 years of planned development have resulted in increasing rice production from 20.6 million tons in 1950-1957 to 38.7 million tons in 1964-1965. In 1964-65, the hectacre yield of paddy in the country was 1074 kg. There has been a corresponding increase of about 17 per cent in the area of rice cultivation. Srinivasan and Rajagopalan (1966)[42] point out that Madras State leads in rice yields with 1480 kg/hectacre. The commodity reports of FAO (1961)[43] attribute the increase of four million tons in paddy production to the increase in both area and yields of the crops in Bihar, West Bengal and Uttar Pradesh.

C. Nutritive Value of Rice:

The chemical composition and nutritive value of the rice diets have been studied by McCollum and Davis (1935)[44], Aykroyd *et al* (1940)[6], Kik (1941)[45], Mason *et al* (1945)[46], Done (1949)[47], Kuppuswamy and Giri (1949)[25], Desikachar *et al* (1956)[48], Warnick *et al* (1956)[49] and Dakshinamurti (1959)[50]. All these studies show that rice is a poor source of protein.

The protein content of rice is lower than that of most varieties of wheat and maize (FAO) (1954)[51], varying from six to nine per cent. Sadasivam and Sreenivasan (1938)[52] reported that coarse and coloured types of rice generally had more protein than the fine grained types.

The quality of rice proteins has been studied by various workers. The FAO (1954)[5] 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. The superiority of rice proteins as judged by PER (Protein Efficiency Ratio) has been reported by Osborne and Mendel (1918)[53], Li (1930)[54], Swaminathan (1937)[55], Basu and Basåk (1937)[56] Kik (1939)[57] and Mitchell and Block (1946)[58].

Through digestability trials with cereals and soya-meal, Hsu and Kung (1948)[59] concluded that rice protein had a higher Biological Value (being 81.3 per cent) than the proteins of millet and soya meal which had a value of only 70.6 per cent. In their human feeding trials Mitra and Verma (1947)[21] and Mitra et al (1948)[22] also registered a high Biological Value for rice protein. The composition of amino acids in rice has been studied by Block and Bolling (1951)[60]. Their data have revealed that rice is deficient in lysine and threonine. The amino acid content of different varieties of rice varies considerably according to the manure added to the soil in which they are grown (1965)[32]. Grist (1960)[61] observes that rice contains about 1.5 to 2 per cent of fat which is located mostly in the outer bran layers and the germ.

Rice is a poor source of calcium and iron, but contains considerable amounts of phosphorous. However, the calcium and phosphorous ratio is unfavourable being 1:10, instead of the desirable 1:2 (1945)[15]. Swaminathan and Bhagavan (1960)[11] and Ghose and coworkers (1960)[3] have reported that rice contains only negligible quantities of calcium ranging from 10 - 12 mg. 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 (1933)[62]. Through feeding trials with different cereals they demonstrated that highest retention of calcium 87.1 per cent occurred from rice as compared with the 73.5 per cent from wheat.

The nature of phosphorous present in rice has been the subject of investigation by Sundararajan et al (1938)[63], Giri (1940)[64] and Ahmed et al (1945)[65]. All these workers are of the view that the aggravation of mineral imbalance in rice diets is due to the presence in it of phytin phosphorous. Several workers have reported on the presence of the B vitamins in rice. The FAO (1954)[5] points out that the thiamine content of rice is higher than the riboflavin content, whereas the quantity of fat soluble vitamins present is only negligible.

Hinton (1943)[66] stated that approximately 50 per cent of the total thiamine were concentrated in the scuttellum, the aleurone layer contained 35 per cent and the embryo 12 per cent. Kik and Williams (1945)[15] pointed out that the thiamine and riboflavin contents differed according to variety. To some extent, the niacin content also varies. Simpson (1957)[67] reported that riboflavin was distributed uniformly throughout the embryo of rice grain. Ascorbic acid is particularly absent in rice (1966)[20].

The loss of nutrients during washing and cooking of rice has been discussed by Malakar and Banerjee (1959)[68]. Basu and Malakar (1946)[69] report that the loss of nutrients is greater during washing and cooking in excess water than when rice was cooked by absorption method. Roy and Rao (1963)[70] point out that the loss of nutrients in rice, especially thiamine, is comparatively less when rice is cooked in moderately alkaline water than when cooked in highly alkaline water.

Deficiencies in Rice Diets:

As early as 1927[71] McCarrison called attention to the superiority of the Sikh diet over the South Indian poor rice diets. He found that the Sikh diet contained wheat along with protective foods, while the South Indian diets, especially the Madrasi rice diet were composed largely of rice with very little protective foods. Wilson and Widdowson (1956)[72] noticed that the incidence of deficiency disease was lower among rice eating communities of the South. The diet surveys carried out in 1948[73] by ICMR revealed the fact that the rice diets of the poor, consisting of 80 per cent rice, with very little protective foods were déficient in several nutrients.

Devadas (1950)[74] observed that the performance of rats on a basal rice diet was poor as evidenced by poor growth and early deaths. Reviewing the work of Bruc and Callow (1934) and Lowe and Steenbock (1936) Giri (1940)[64] stated that phytin phosphorous was not completely available from rice diets. He pointed out that the major deficiency of the poor rice diets was calcium.

Aykroyd and Rajagopal (1936)[75] reported that the deficiencies of vitamin A, niacin and iron along with calcium were more crucial than protein deficiency in rice eating populations. Aykroyd and Krishnan (1937)[7] reported that phrynoderma was associated with rice diets which were deficient in protective foods.

Aykroyd and Swaminathan (1940)[76] observed that the South Indian rice diet was poor in nicotinic acid. Aykroyd and Krishnan (1938)[77] noted the occurence of angular stomatitis among the South Indian populations who were subsisting on milled rice with negligible quantities of vegetables and other protective foods.

Ramalingaswamy (1948)[78] found occular symptoms of vitamin A deficiency along with severe diarrhoea in poor children in a plantation area in South India. Their diets were based mainly on rice and were inadequate in calories, vitamin A, thiamine and calcium. Ramalingaswamy and patwardhan (1949)[79] observed that deficiency of nutrients such as vitamin A, thiamine and calcium in the diets of South Indian plantation labourers. Aykroyd (1930)[80] described a deficiency state marked by dermatitis in rats fed a basal rice diet consisting of milled rice. Reviewing the work of Sukhatme (1965), Panse (1967)[81] warns that an average Indian consumes a diet with lesser calories and protein than his counter part in the developed regions. Therefore India has to fill a quantitative and qualitative gap in the nutritive value of her diets.

<u>Types of Rice Differently Processed</u>:

Kernel length has been used in most rice growing areas as a characteristic for classifying rice varieties. Graham (1913)[82], Beale (1927)[83] and Hector (1934)[84] have used the kernel width and thickness for the classification of rice. Graham (1913)[32] divides the rices of India into 'long spikelet', 'fine', 'coarse', and 'round' types. Rice varieties in the United States of America are generally indicated as 'long', 'medium', and 'short'. When Graham's classification is applied to Indian rice, the 'fine class' of the United States is equivalent to 'long spikelet', the 'medium class' to 'coarse grain', and the 'round class' to 'short grain'.

There is little variation in the chemical composition of the different types of rice grains. Simpson et al (1965)[35] have reported on the protein, fat, amylose, amylopectin and starch contents of the different varieties of rice. The lipid content of long grain varieties is higher than that of medium grain and shorter grains. Long grains have the highest amylose content. Parboiling increases the amylose, amylopectin and starch contents in all the three types.

1. Raw and Parboiled Rice:

Nearly 50 per cent of the paddy produced and marketed in India is milled in the parboiled state (1965)[32]. During the process of parboiling the endosperm of the grain swells and the constituents of the bran permeate into the interior resulting in the retention of nutrients (Srinivasan) (1938)[36]. Williams (1960)[37].

stated that two thirds of the world population preferred to have rice in the white form, except in India and Ceylon, where about 180 million people use rice in the parboiled form which is brown in colour. Further Williams recommends the use of parboiled, hand pounded or unmilled rice and the enrichment of rice, as preventive measures against beri beri.

Parboiled rice has been considered as the best type, since parboiling increases the nutritive value of rice and favours the retention of thiamine, riboflavin and niacin during milling, washing and cooking. Aykroyd (1932)[88] and Subrahmanyam et al (1938)[89] (1955)[90] demonstrated that parboiled rice retained a considerable proportion of the nutrients, protein, thiamine and phosphorous even when highly milled. Acharya et al (1942)[91] observed that the proteins of parboiled milled rice with a high Biological Value promoted greater increase in the rate of growth in rats than that effected by the proteins of raw milled rice. The retention of nitrogen is also higher in the endosperm of parboiled rice and it contains higher amounts of protein than raw rice (Subrahmanyan et al) (1936)[92]. Srinivasan (1936)[93] pointed out that parboiled rice is generally poorer in fat than raw rice. Srinivasan (1938)[86] is of the view that there is a considerable movement of the fat constituents from the germ into the bran when parboiling takes place. Even then, parboiled rice retains six per cent more fat than raw rice.

It has been reported by many workers that there was a considerable increase in the levels of calcium and phosphorous and available iron when rice was parboiled. Subrahmanyam et al (1938)[39] inferred that on parboiling, part of the nitrogen and phosphorous present in the germ was transferred to the endosperm. Hinton (1948)[94] demonstrated that in parboiling, redistribution of the thiamine in the grain took place with the result the endosperm was considerably enriched. FAO (1954)[6], Ramamurthy and Gopalan (1964)[14] state that parboiled rice contains more thiamine and other nutrients than raw rice. Kik (1959)[95] reported that substantial increase in thiamine, riboflavin, niacin and other B-Complex vitamins resulted when rice was parboiled.

Sarby and Tonnus (1960)[96] 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)[97] reported a loss of 30 per cent of thiamine during the parboiling process mainly due to oxidation.

The losses occurring in nutrients while washing and cooking of rice have been pointed out by various workers. Swaminathan (1941)[16], (1942)[17], Kik and Williams (1945)[15] and Swaminathan and Raghavan (1960)[11] have recorded appreciable retention of nicotinic acid, thiamine and other nutrients such as protein and minerals in parboiled rice, even after washing and cooking, as compared to raw rice, treated similarly. Srinivasan (1951)[98] estimated that the losses in washing and cooking of parboiled rice were of the order of 4 - 10per cent for protein: 15 - 30 per cent for minerals; and 30 per cent or more for the B Complex vitamins.

The effects of parboiling on the volume, colour and soluble starch content have been investigated by Roberts et al (1954)[99]. Simpson et al (1965)[85] state that parboiled rice averages slightly higher in amylose content than raw rice and also has a higher amylose, amylopectin ratio. Roberts et al (1954)[99] noted that parboiling increased the content of soluble starch as revealed by the higher starch iodine blue value in parboiled rice samples than in milled rice.

2. Dehusked, Hand Pounded and Milled Rice:

Dehusking, hand pounding and under milling are methods which help to retain nutrients to the maximum extent in the rice when paddy is processed. 'Dehusked rice' is also known as 'Hulled rice' or 'Brown rice' and is obtained when the husk is removed from the rice (1954)[5]. Recently different types of hand operated dehuskers have been devised for processing rice under the promotional efforts of the Khadi and Village Industries Commission.

'Hand pounded' rice is also known as 'home pounded' rice which is prepared by using a pounding apparatus. Hand pounding is an ancient practice for dehusking rice in the village homes. The implements used for hand pounding are the chakki and the pestle and mortar.

Milled rice is the rice obtained from milling the rice in a power driven machinery. In many cases, polishing is given simultaneously. Milled raw rice is usually white in colour (1954)[5].

The chemical composition and nutritive value of differently processed rice have been studied by many workers. The nutritive value of hand pounded and dehusked rice has been found to be higher than that available after the removal of bran which is rich in the nutrients like thiamine, protein and minerals (1960)[11]. Joachim and Kandiah (1929)[100] proved the superiority of undermilled rice in terms of its protein and calcium contents. Basu and Sarkar (1936)[101] reported that milling resulted in a marked decrease in the mineral and fat contents. FAO (1954)[5] states that the degree of milling and polishing affects the nutrient contents of rice, since higher degree of milling removes the aleurone layers which are rich in nutrients. Kik and Williams (1945)[15] reported on the loss of minerals and vitamins during the milling of rice.

Reviewing the work of Juliano et al (1964) (1964) and Oke (1965), Juliano (1966)[102] noted that milled rice contains 6.5 - 13.3 per cent protein with a fat content ranging from 0.3 to 0.6 per cent. Hogan (1964)[103] and Hogan (1966)[104] and Normand et al (1966)[105] have analysed the protein content of rice milled to varying degrees. They state that concentration of protein is higher near the periphery of the whole grain whereas it may be lower in the outer most layer, if this layer is high in bran constituents.

The amino acid composition of milled rice has been studied by Babtist (1954) and Kik (1965) and reviewed by Juliano (1966)[102]. They have reported about the lower concentration of amino acids, especially, lysine in milled rice. Kik (1943)[106] and Dakshinamurthy (1955)[107] observed that the B - vitamins were present in lesser amounts in milled rice than in hand pounded and dehusked rice.

Subrahmanyam and Swaminathan (1956)[108] and Subrahmanyam et al (1956)[109] reported that husked rice had a higher content of phytate phosphorous and considerably higher quantities of protein, B-vitamins and minerals, than milled and under milled rice. Guha and Mitra (1963)[110] studied the protein content of brown rice which is found to be higher than the milled rice. Ranganathan et al (1937)[111] showed that the loss of calories and nutrients during the milling of rice were: calories 15 per cent; protein 10 per cent; iron 75 per cent and calcium and phosphorous 50 per cent.

Hand pounded or home pounded rice has been considered as the best processed rice next to dehusked rice by Swaminathan and Bhagavan (1960)[11]. As early as 1924, Block and Mitchell[112] found that the proteins of brown rice were superior to those of maize and oats diets. Sure and House (1948)[113] stressed the superiority of the proteins of brown rice because of its higher Biological Value, 85 per cent, as compared with, the 63.1 per cent of milled rice. Jones et al (1948)[114] also showed that the proteins of brown rice surpassed those of polished rice in Biological Value.

Rao et al (1960)[115] state that the phytic acid which is present in larger amounts in brown rice, interferes with the utilisation of dietary calcium as evidenced through calcium balance studies in human beings. They concluded that the nitrogen and phosphorous retention affected by brown rice was not higher than that accomplished by milled polished rice.

Miller (1945)[18], Vinacke (1951)[19] and Kennedy and Tsuji (1952)[116] noted that washing and cooking losses of nutrients were negligible in the case of brown rice. Chatterjee et al (1956)[117] and Gupta et al (1953)[118] analysed the amino acid composition of brown rice and found it to be higher than that of milled rice.

Efforts to [redacted] the [redacted] of Rice:

Numerous efforts have been initiated to improve the nutrients in rice. They are:

1. Hybridization:

The major objective for undertaking rice breeding projects in India is to develop high yielding types, and distribute them to the farmers in the different parts of the country. Besides the 'Central Rice Research Institute' in Cuttack, there are 32 Rice Breeding Stations. Out of these, eight are located in Madras state (1960)[3].

The early experiments in hybridization date back to 1939, when Sadasivam and Srinivasan (1939)[119] reported on the nutritive value of an improved strain of rice, in which there was increase in the levels of protein, calcium and phosphorous. 'The International Rice Hybridization Project' was started in 1950 under the auspices of the FAO (1954)[120]. Today as the result of vast agronomic developments in rice breeding, improved strains of rice crops are being evolved extensively. The improved strains have desirable economic characteristics such as higher yield, better quality, greater resistance against diseases and superior nutritive value ICAR (1966)[121]. For the commercial production of hybrid rice, a series of studies have been initiated at various rice research centres throughout the world by the intentional use of hybrid vigour in rice (Stansel and Craigmiles). (1966)[122].

From 1951 onwards, the collaboration between the FAO and 'ICAR's State Breeding Centres' has succeeded in evolving new hybrid strains as cross between Indica and Japonica. The hybrid strains of rice which have been recently evolved in Madras State are GEB - 24, Co - 25, Co - 29, Co - 30, ADT - 3, ADT - 27, ADT - 23, TKM - 6 and ASD - 13 (1966)[41]. Swaminathan (1967)[123] states that qualitative improvements has also been achieved through breeding in cereals. Thus the protein content of rice varieties has been raised from 8 to 15 per cent, through artificial induction of mutations.

2. Influence of Fertilizers and Environment on the Nutrient Content of Rice:

As early as 1928 McCarrison[124] reported that rice grown under swampy conditions contained greater per centage of protein and mineral matter than that grown under rainy conditions. Sturgis and Reed (1937)[125] recorded an increase in the cystine, tryptophan, lysine, arginine and histidine contents of rice by the use of fertilizers. They noted that when the soil was high in iron, the iron content of the rice was also higher.

Ramiah and Mudaliar (1939)[126] observed that the protein and mineral content of rice can be increased by proper manuring as in the case of wheat and barley. Sathe *et al* (1948)[127] found that the nature of fertilisers applied to the soil had some influence on the thiamine content of rice.

Chitre *et al* (1955)[128] pointed out that soil nutrition and environmental conditions influenced the nutritive value of all plant foods. As such, two different strains of the same variety are likely to show variation in nutrient content, if cultivated under different environmental conditions.

3. Rice Enrichment:

The purpose of enriching rice is to add nutrient to milled rice, in order to give a desirable nutrient content to the resulting product, especially in those countries where white rice is cooked in excess water and the cooking water discarded. Rice enrichment originated from the Philippines during the year 1948 to 1950 (1952)[129], (Williams) (1961)[130]. By 1951 the number of people who were encouraged to consume the newly available rice to overcome the deficiency beri beri rose to 1,800,000.

Furter *et al* (1946)[131] developed fortified 'premix' in which rice is sprayed with minerals and vitamins mixed with phrophosphate, and finally sprayed with sein and fatty acids. Watanabe et al (1960)[132] report that in

Japan enriching rice with O, S, dibenzoyl thiamine (DBT) proved to be as effective as addition of thiamine. These authors state that rice can be enriched also with the amino acids lysine and threonine which are normally deficient in rice. Enriching rice with amino acids has also been suggested by Kik (1956)[133].

The Japan Nutrition Association (1956)[134] reports about the benefits of the addition of calcium carbonate to rice. Bhattacharya (1964)[135] describes a simple method of enriching rice with riboflavin. He has given also a satisfactory method for the enrichment of white rice with minerals and vitamin using heat processing.

4. Parboiling or Conversion:

Since parboiled rice is more nutritious than raw rice, the consumption of parboiled rice needs to be encouraged. However, the prevailing poor methods adopted in parboiling paddy have resulted in creating resistance against the use of parboiled rice by the consumers (1960)[3]. Therefore improved methods of parboiling paddy are being developed. Subrahmanyan *et al* (1955)[136] describe the method called 'Hot soaking method' which proved successful in preventing growth of fungi and the development of off-flavours. Another improved method is the 'Hot soaking process cum hypochlorite treatment'. Rao (1955)[137] recommends a method in which, instead of converting and parboiling rice, the rice is treated chemically using area. This method is reported to have the advantage of imparting a good flavour to rice.

G. Supplementing rice Diets with Minerals, Vitamins and Amino Acids:

Several workers have suggested different ways by which the nutritive value of rice diets can be enhanced (Lal) (1952)[138], (Moorjani and Subramanyan) (1953)[139], (Lily et al) (1956)[140] and (Chandrasekaran et al)(1955)[141]. These procedures involve the partial replacement of rice by other cereals and roots and also supplementation of rice diets with protein rich foods, minerals and amino acids (1954)[5]. Partial replacement of rice with jowar has been encouraged by Kurien et al (1930)[142]. Jowar is a richer source of protein and the B complex vitamins than rice. The protein content of jowar ranges from 9.7 to 10.3 per cent (Kurien et al) (1960)[143]. Striking improvements in the growth of albino rats and school children were observed by Mason et al (1946)[46] when a part of rice was substituted with ragi. Kurien et al (1960)[144] state that replacement of even a small part, namely 25 per cent of the rice in the diets by ragi would be adequate to make up the calcium deficiency in the poor rice diets.

Pasricha and Rao (1965)[145] observe that when rice cooked with 'chunnam' (calcium hydroxide) treated water, the calcium content of cooked rice found to be three time more than raw rice and also the body weight of rats fed with this rice was increased.

Harper et al (1955)[146] and Deshpande et al (1955)[147] have demonstrated that the addition of amino acids such as lysine, threonine and methionine improved the rice diets as evidenced by the improved growth rate in rats. Wikramanayeka et al (1961)[148] noticed considerable improvements in the growth of children suffering from kwashiorkor in Ceylon when their rice diets were supplemented with amino acids lysine.

Normand et al (1966)[106] refer to the results of investigation which confirmed the protein distribution in rice kernels reported by various workers. They demonstrated the presence of high protein bearing layers on kernels of rice varieties. High protein rice flours have been prepared by a specially designed mill, and the prepared material was removed in 12 fractions from successive layers of milled rice, which furnished 13 per cent of the kernel weight and with 12 to 22 per cent of protein content. Hogan (1966)[151] states that the content of fat, thiamine, riboflavin, niacin, phosphorous and calcium have been increased in such a high protein rice flour.

Because of these benefits Hogan (1966)[152] anticipates a high demand for high protein content flour for incorporation into baby foods, and as supplements and substitutes for protein.

III EXPERIMENTAL PROCEDURE

The experimental procedure consisted of the following steps:

A. Selection of the strains of paddy.

B. Parboiling paddy.

C. Dehusking paddy.

D. Hand pounding paddy.

E. Milling paddy.

F. Cleaning and winnowing the differently processed rice samples derived from the selected strains of paddy.

G. Nutrient analysis of the differently processed rice samples for: calories, protein, total ash, calcium, phosphorous, iron and thiamine.

H. Interpretation of the findings.

A. Selection of the strains of paddy:

Two strains of paddy were necessary for the study: the improved strain ADT-27 on which this investigation was based, and a local strain for comparison purposes.

1. Selection of ADT-27:

ADT-27, which is an improved hybrid strain of paddy was selected for the study. It has been recently developed by crossing a Japonica variety (Norin 3) with an Indica variety (GEB-24) as the result of the India Japonica Rice Hybridisation Project, at Aduthurai Rice Research Station (Madras State) and released in 1964. It is reported to be capable of: utilising heavy doses of chemical fertilisers withstanding loding, and producing high yield. Being a crop of short duration of 105 days, ADT-27 has been rapidly multiplied through a special scheme for covering the entire 'Kuruvai'* area under the Mettur Irrigation system in the Cauvery Delta. This strain has given an average yield of 4000 lb of paddy per acre which is nearly double the average of the existing varieties.

The requirement for the experiments designed for this study was calculated to be 180 kg. of ADT paddy. This was purchased in one lot from the paddy Breeding Farm of the State Agricultural College and Research Institute, Coimbatore.

1. Selection of the local strain:

The local strain ASD-5 (abbreviation for Ambasamudram 5) is popular in Coimbatore. It is a pure line strain from the variety 'Karthigai samba'. It has an yield 3000 - 4000 lbs., per acre which is higher than that of its parent strain. It is a medium duration crop of 135 days and can be cultivated in almost all the paddy growing areas. The rice obtained from ASD-5 paddy is white in colour. The requirement of 180 kg. of ASD-5 was also obtained from the State Agricultural College and Research Institute.

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* The term 'Kuruvai' indicates the first rice crop season in Tamil Nad, derived from the word 'Kar'. It has a short duration of about 3½ months extending from June to September.

B. Parboiling paddy:

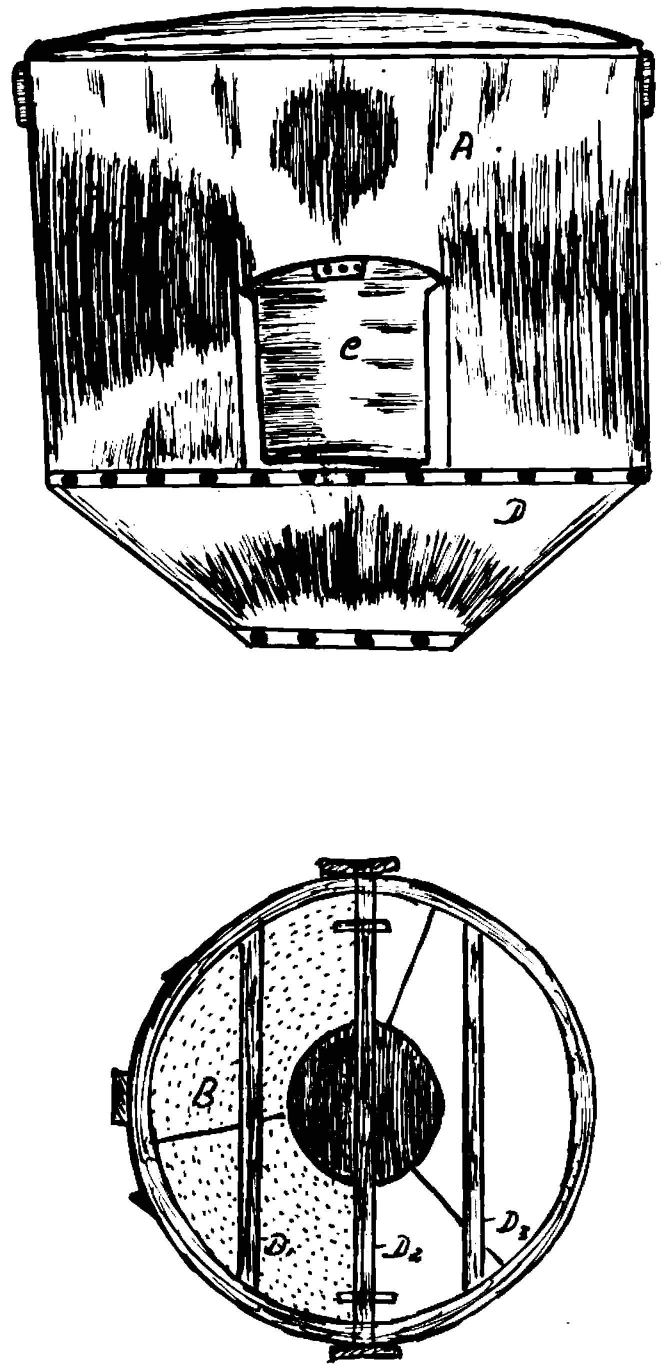
Parboiling is an ancient practice in India. In parboiling, paddy is steeped in water for hours together over night, or for many days, steamed subsequently till the outer husk of the paddy burst open, dried and husked. The method used by the rice trade allows for prolonged and uncontrolled fermentation in soaking tanks. Such a practice affects adversely the colour, odour, cooking quality, acceptability and nutritive value of parboiled rice, as has been pointed out by several workers. In order to eliminate such fermentation Rao and Guha (1952)[153] suggested the possibility of soaking paddy at a temperature 65--70°c, instead of soaking it in cold water for two to three days.

Based on their suggestion Subrahmanyam et al (1955)[90] developed an improved method of parboiling through 'Hot soaking Process.' They soaked the paddy in hot water at a temperature 70--75°c for about three hours, at the end of which the water was let out and paddy steamed in cylindrical kettles provided with steam coils, till the outer husk burst open, the steamed paddy was dried in the shade.

Adopting a similar procedure, the parboiling process for this study was standardised, with the use of the Kallupatti parboiler - Figure 1 - devised by the Rural Extension Training Centre at Kallupatti, Madras State.

FIGURE - 1

THE KALLUPATTI PARBOILER



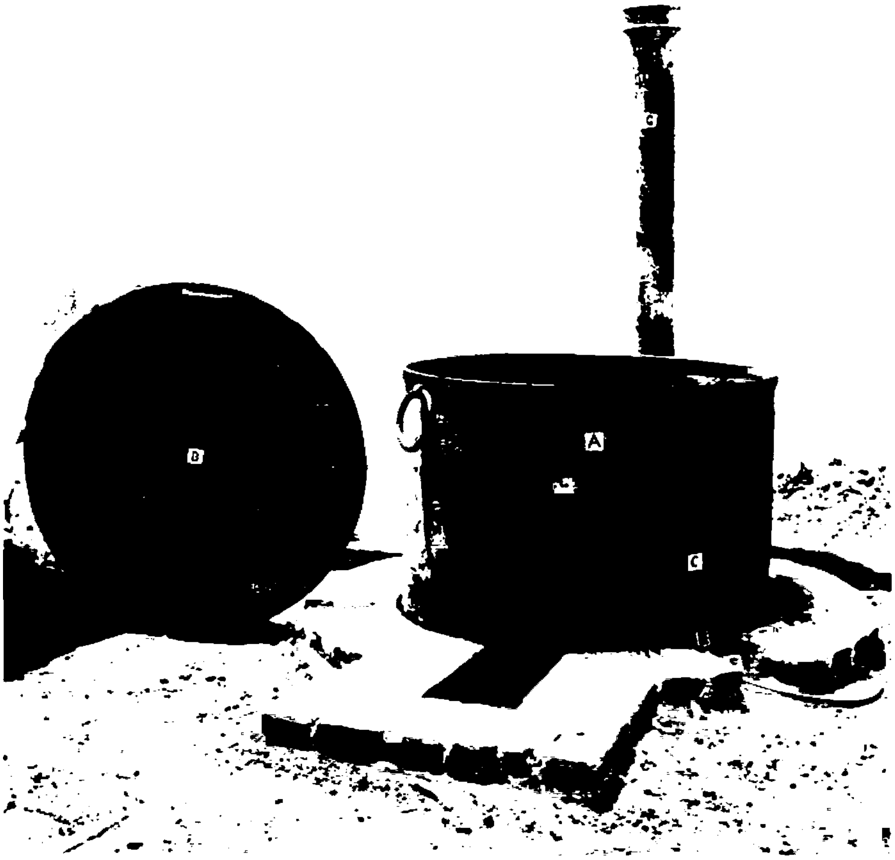
The parboiler has a cylinderical parboiling drum (A) with a perforated sieve (B) at its bottom, and a door (C) at the side. The bottom of the boiler has the shape of an inverted cone (D), the cylinderical tank (A) is 3'3" in diameter and has two handles at the open end. The perforated sieve (B) has a diameter of 3'1" which is less than the diameter of the drum and is sligh-tly convex. It has two handles at the open end. The holes on the sieve are small enough not to let the paddy pass through. This sieve is supported on three cross bars ['d'$_1$] ['d'$_2$] ['d'$_3$] near the joint of the drum with the inverted cone. The door has a shutter arrangement sliding up and down which can be adjusted or removed for drawing out the parboiled paddy. It has the capacity of parboiling 120 kg. paddy at a time.

Standardisation of the parboiling process:

For standardising the soaking and steaming process certain modifications were effected to the Kallupatti Parboiler - Figure 2 -. The door with the shutter arrangement was completely sealed to avoid leakage of water from the drum and also make the soaking effective. A tap (E) with a rubber tube (F) was attached outside at a place one inch below the door and two inches below the level of sieve to drain the water off from the paddy after soaking so that the water would remain at a level below the sieve to facilitate steaming. The rubber tube was connected

FIGURE . 2.

KALLUPATTI PARBOILER WITH MODIFICATION



to the tap to avoid water falling into the choola. This arrangement facilitated the carrying out of both soaking and steaming in the same utensil which amounted to a considerable saving in labour and heat.

The choola was constructed specially for this purpose with bricks, in a round shape below the ground level in such a manner that firewood can be used as fuel. The depth of the choola was 1'6".

Using the principles of 'hot soaking', the standardisation of the parboiling process was effected in the following manner.

Trial experiments were carried out in the beginning on a small scale. One kilogram of paddy was used for this purpose each time in an ordinary household utensil. The time required for soaking, steaming and for drying of the parboiled paddy was noted. It was found that one kilogram of paddy soaked for two and half hours in water at a temperature 70--75°c, and steamed for three minutes proved to be satisfactory.

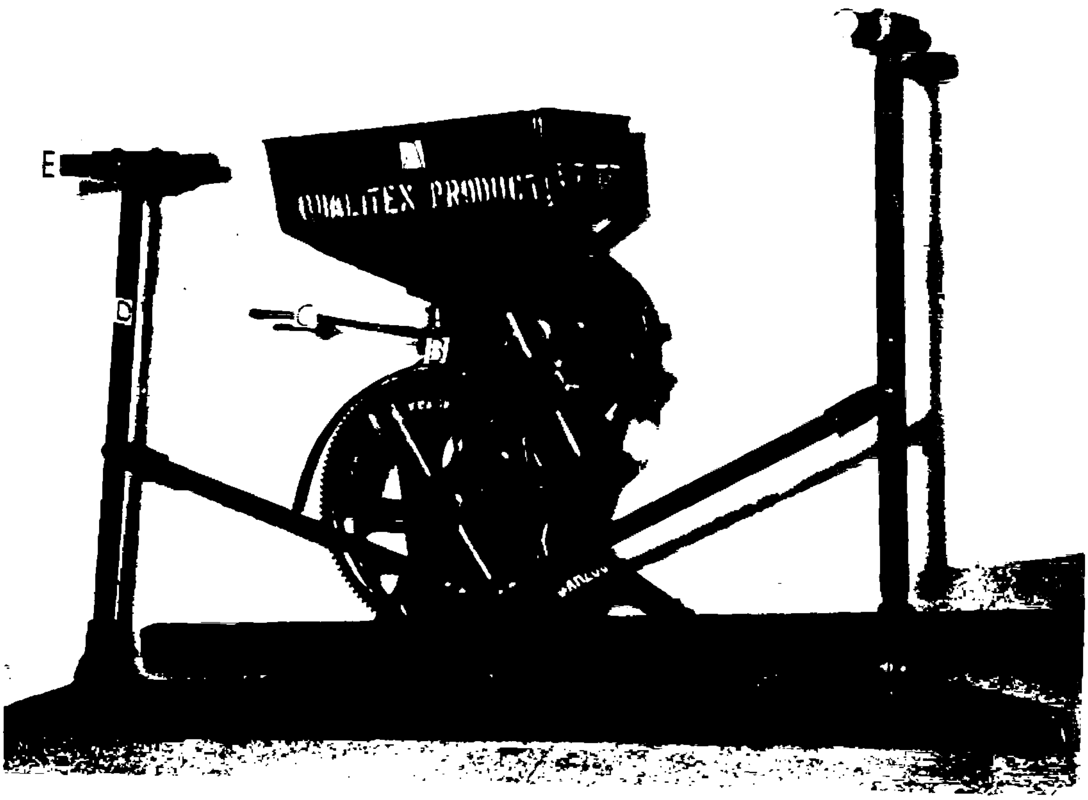
This was repeated on a larger sample with five kg. of paddy using the modified Kallupatti parboiler. The paddy was soaked in hot water which was maintained at a temperature

70--75°c for two and half hours and subsequently steamed about five minutes, till the outer husk of the grain burst open, shade drying was followed rather than drying in the sun, which has been found to give satisfactory results in terms of the quality of rice. Govindaswami and Ghosh (1965)[154] have also advocated this method of drying paddy.

The parboiler was filled with 148.4 litres of water and heated over the choola to a temperature 75° - 80° c for one hour. Thirty kg. of the paddy were added to the water above the sieve in the drum. The level of water was maintained at three inches above the paddy, by adjusting the level drawing out from the tap. When the paddy was added to the water, there was a drop in temperature to 70°c. The parboiler was covered with a wooden plank and the temperature inside was maintained at 70° - 75°c, by adjusting the burning of the fire wood under the cone. Every half an hour the temperature was noted and the paddy was stirred with a laddle for eveness in soaking. The water was drained off after two and half hours, and the paddy steamed five minutes in the same utensil until the outer husk burst open. The steamed paddy was next transferred to a basket, spread on the floor evenly as a thin layer and dried in the shade at room temperature. It was turned at intervals of one hour, for about three days.

FIGURE - 3.

PADDY DEHUSKER



C. Dehusking paddy:

The implement selected for dehusking paddy in this investigation was a gear driven paddy dehusker* as shown in Figure (3) as recommended by the Khadi and Village Industries Commission. The dehusker has a hopper (A) to hold the grain. Below the hopper is the machine (B). This has a wheel guard of small gear and the paddy chamber which has an adjusting plate and handle (C) for the same. The dehusker has levers to operate (D) with two wooden gripes (E). It has a capacity to dehusk 200 kg of paddy in one hour. The paddy is hulled by the simulteneous, vigorous downward and upward motions of the handles by the two men, at the speed recommended.

The dehusking procedure was standardised through trial experiments conducted with three kilograms of paddy. When the machine gained a speed of 50 revolutions per minute, the paddy was let into the huller by releasing the shutter. The two rubber rollers inside, rotate in directions opposite to each other and dehusk the paddy when it passes through the space between them. The feeding plate (C) was opened gradually and finally fully to remove the rice. The product thus obtained was 'brown rice'. The dehusked brown rice was cleaned with the winnower shown in Figure(4), as per procedures recommended by the Khadi and Village Industries Commission.

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* Gear Driven Paddy Dehusker (Model Naveen--GPH 200) — Qualitex Machinery Ltd., Kirti Nagar, New Delhi.

FIGURE . 4.

WINNOWER

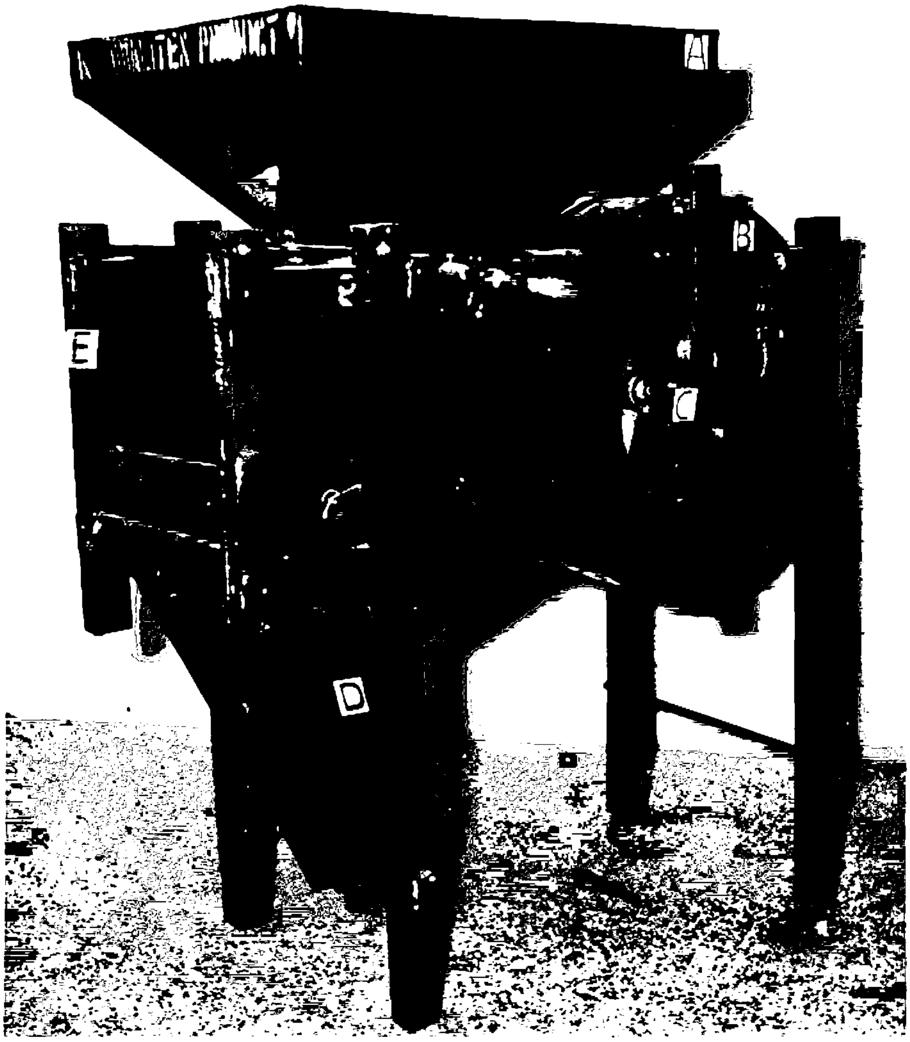

FIGURE . 5.

THE PESTLE AND MORTAR

The winnower has a hopper (A) to hold the rice and husk below which is a winnowing chamber (B) provided with a fan inside and a handle (C) to operate the winnower (D) denotes the two separators below to discharge the cleaned rice through the opening (E). The husk fanned out as the huller operates.

D. Hand Pounding of paddy:

The ICAR (1960)[3] defines hand pounding as milling of rice in small quantities, using various types of traditional equipment. Among the implements available for hand punding paddy, 'The Pestle and Mortar' shown in Figure (5) is mainly used in Madras State for dehusking and polishing rice. Therefore the hand-pounding in this study was done by using the 'Pestle and Mortar'.

With the view to reduce per centage of broken rice and to increase the efficiency of hand pounding in terms of the removal of maximum husk, the hand pounding was standardized as follows:

Seven hundred and fifty grams of paddy which was the capacity of the mortar (A) were used and pounded by two women. The number of strokes were counted and the time noted. The paddy in the cavity (B) was turned after three to four minutes of pounding with the pestle (C) for eveness. The number of strokes ranged from 20 to 30 per minute. Thus the standardised procedure for hand pounding, involved pounding 750 kg of paddy by two women stopping at every 30 strokes for about 5 minutes. The time taken to pound 10 kg of raw or parboiled paddy was 120.7 minutes.

E. Milling paddy:

The paddy was dehusked and polished at a local mill, operated electrically. The standardisation was carried through trial experiments on the three kilograms of paddy. The machine was adjusted for its speed and accuracy. The paddy was dropped into the hopper and the screw released. The lid was opened and the paddy was allowed to pass through grinders. The paddy was milled for four minutes and polished once, according to the practice invogue in Coimbatore city. The same procedure was used for milling ten kilograms each of raw and parboiled paddy. The time taken was 12 minutes.

F. Cleaning and winnowing the differently processed samples of rice:

The differently processed rice samples were cleaned and winnowed to remove the husk, immature (hallow) paddy, chaff and dust, by using the winnower, for five minutes at a speed of 90 revolutions per minute.

G. Chemical analysis of the samples of differently processed rice:

Calories:

The calorific content of the sample of rice was analysed by using the Parry's Oxygen Bomb Calorimeter (1964)[155].

Protein:

The protein content of the sample of rice estimated by the Microkjedahl method as described by the A.O.A.C. (1960)[156] using the conversation factor 5.9 for the calculation of protein.

Total ash:

Total ash was estimated as per the method given in A.O. A.C. (1960)[156].

Calcium:

Calcium was estimated by the titrimetric method by the A.O.A.C. (1960)[156].

Phosphorous:

The phosphorous content was determined by the Fiske and Subba Rao's method (1954)[157].

Iron:

Iron was estimated by using the method of wong as described by Hawk et al (1954)[157].

Thiamine:

For the estimation of thiamine, the thiochrome method was used as described by A.O.A.C. (1960)[156].

H. Interpretation of the Findings:

Calculation for Standard Error:

The sample standard error is symbolished by $S\bar{x}$ 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:

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

$$S = \sqrt{\frac{\Sigma x_i^2 - (\Sigma x_i)^2/n}{(n - 1)}}$$

Calculation for 't' values:

Comparison between the two strains of rices and the differences between the raw and parboiled rice samples and the milled, hand pounded and dehusked samples were analysed using the 't' test (Senedecor, 1960)[158].

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S\bar{x}_1 - \bar{x}_2}$$

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

IV RESULTS AND DISCUSSIONS

The analyses in this investigation included determinations of:

A. Calories

B. Protein

C. Total ash

D. Calcium

E. Phosphorous

F. Iron

and G. Thiamine

Thus the discussions would cover the nutritive value of the rice obtained from the two strains, ADT_{27} and ASD_5 after milling, dehusking and hand pounding in the raw and parboiled forms.

A. Calories:

The calorie content of the raw and parboiled rice samples of the two different strains, ADT_{27} and ASD_5 after milling, hand pounding and dehusking are presented in Table I, and the statistical calculations are given in Appendix II.

TABLE I

THE CALORIES PER 100 G. OF RICE PROCESSED DIFFERENTLY

Stain of Rice	Raw Rice: Milled	Raw Rice: Hand Pounded	Raw Rice: Dehusked	Raw Rice: Mean	Raw Rice: 't' value	Proboild Rice: Milled	Proboild Rice: Hand Pounded	Proboild Rice: Dehusked	Proboild Rice: Mean	Proboild Rice: 't' value	Raw VS Probailed: Mean	Raw VS Probailed: 't' value	ADT27VS ASD5: Grand Mean	ADT27VS ASD5: 't' value
ADT 27	377	391	408	392		331	392	418	397		392			
												0.1688	394.5	
					3.033**					3.144**	397			4.410**
ASD 5	338	361	392	363		343	366	393	367		363	0.3660		
											367		365.6	

** Significant at 1 per cent level.

* Significant at 5 per cent level.

As seen from the figures in Table I, the differences in the caloric content between the raw rice obtained from ADT_{27} and ASD_5 was highly significant, whether milled, handpounded or dehusked, ADT_{27} possessing the higher value. The data further reveal that similar significant difference was found between the corresponding parboiled rice of ADT_{27} and ASD_5. Taking both raw and parboiled samples together, the strain ADT_{27} has significantly higher caloric content. The triplicate values and the statistical appraisal are given in Appendices I and II respectively.

The caloric value obtained for the strain ADT_{27}, in this study is also much higher than the values 345 to 360 calories/100 g given by Aykroyd et al (1966)[20].

Table II presents the differences between the caloric contents of the two strains of rice which have undergone different processes for the removal of the husk.

The details of the figures for mean, 't' value, and standard errors are presented in Appendix III.

TABLE II

EFFECT OF MILLING, HAND POUNDING AND DEHUSKING ON THE CALORIC CONTENT OF THE RAW AND PARBOILED ADT_{27} AND ASD_5.

Strain	't' Value	Strain	't' Value
ADT_{27}		ASD_5	
1. Raw Milled vs Raw Handpounded	2.432	Raw Milled vs Raw Handpounded	9.305**
2. Raw Milled vs Raw Dehusked	4.933**	Raw Milled vs Raw Dehusked	10.73**
3. Raw Handpounded vs Raw Dehusked	6.050**	Raw Handpounded vs Raw Dehusked	13.50**
4. Parboiled Milled vs Parboiled Handpounded	2.356*	Parboiled Milled vs Parboiled Handpounded	9.305**
5. Parboiled Milled vs Parboiled Dehusked	9.065**	Parboiled Milled vs Parboiled Dehusked	16.67**
6. Parboiled Hand-pounded vs Parboiled Dehusked	7.762**	Parboiled Handpounded vs Parboiled Dehusked	2.505

* Significant at 5 per cent level
** Significant at 1 per cent level

As seen from Table II, there is not much difference between the caloric contents of the samples of raw rice of ADT_{27} after milling and handpounding. But the difference is highly significant at 1 per cent level, between the caloric content of raw milled and raw dehusked, and between raw hand pounded and raw dehusked samples of rice of ADT_{27}. In the case of ASD_5, the difference is highly significant between the raw milled sample and the raw hand pounded or dehusked samples. In the case of parboiled rice both of ADT_{27} and ASD_5, significant difference in the caloric content is noticed between the milled and dehusked products. The difference is found between the parboiled milled and hand pounded sample of ADT_{27} and significant at 5 per cent level. But the difference between the caloric content of parboiled hand pounded and dehusked ASD_5 is not significant.

In view of these differences it is concluded ADT_{27} has higher caloric content than ASD_5 and also when compared with the reported caloric values for rice in the literature. Dehusking conserves the maximum caloric content, possibly due to the fibre being in tact in the dehusked rice. How far these additional calories available are physiologically available for the human being needs further study.

B. Protein:

Table III gives the protein content of the differently processed rice obtained from the two strains ADT_{27} and ASD_5 with the replicate values and the statistical appraisal in Appendices IV and V respectively.

TABLE III

PROTEIN PER 100 G. OF THE DIFFERENTLY PROCESSED RICE

SAMPLE OBTAINED FROM ADT27 AND ASD 5

Strain of rice	Raw Rice					Parboiled Rice					Raw VS Parboiled rice		ADT 27 VS ASD 5	
	Milled	Hand Pounded	Dehusked	Mean	't' value	Milled	Hand Pounded	Dehusked	Mean	't' value	Mean	't' value	Grand Mean	't' value
ADT 27	10.11	10.57	10.65	10.44		10.14	12.35	12.96	11.81		10.44 11.81	3.672**	11.12	
					7.721**					9.583**				11.9**
ASD 5	7.77	7.88	8.20	7.94		7.80	9.02	9.36	8.75		7.94 8.75	9.908**	8.35	

** Significant at 1 per cent level.

* Significant at 5 per cent level.

From the figures in Table III, it is evident that all the parboiled samples contain significantly greater protein content than the corresponding raw samples. These findings agree with the earlier observations of Ranganathan (1938)[111] and Swaminathan and Bhagavan (1960)[11] on the beneficial effect of parboiling on the protein content of rice. Significant differences are also noticed between the protein contents of the two strains of rice both in raw and parboiled ADT_{27} containing higher amounts.

It is thus evident that the new strain ADT_{27} has significantly higher amounts of protein 10.44 g. per cent in the raw state and 12.81 g. per cent in the parboiled state almost equal to the protein content of wheat. This far exceeds the values reported by (Grist 1960)[61] and Aykroyd et al (1966)[20], which ranges from 6 to 8 per cent in both raw and parboiled products.

The proteins of rice are considered superior because of their high Biological value. Hence it will be of interest to find out the Biological Value of the proteins of ADT_{27}. However, rice proteins are a poor source of the amino acid lysine. Whether or not such a picture exist on ADT_{27}, which has a higher amount of protein in the raw and parboiled form needs investigation.

Several investigators have reputed on the nutrient content resulting from parboiling rice. As stated by

Subrahmanyan et al (1938)[136] parboiling effects the transformation of the nitrogen present in the germ in to the endosperm of rice grain.

The differences in the protein content of the rice obtained from ADT_{27} and ASD_5, due to the processes applied for removing the husk are presented in Table IV as 't' values and the statistical appraisal is given in Appendix VI.

TABLE IV

EFFECT OF MILLING, HANDPOUNDING, AND DEHUSKING ON THE PROTEIN CONTENT OF ADT_{27} AND ASD_5

Strain	't' Value	Strain	't' Value
ADT_{27}		ASD_5	
Raw Milled vs Raw Handpounded	8.954**	Raw Milled vs Raw Handpounded	1.434
Raw Milled vs Raw Dehusked	12.55**	Raw Milled vs Raw Dehusked	3.390**
Raw Hand-pounded vs Raw Dehusked	5.358**	Raw Handpounded vs Raw Dehusked	2.783*
Parboiled Milled vs Parboiled Handpounded	31.67**	Parboiled Milled vs Parboiled Handpounded	15.66**
Parboiled Milled vs Parboiled Dehusked	5.320**	Parboiled Milled vs Parboiled Dehusked	10.61**
Parboiled Handpounded vs Parboiled Dehusked	4.095**	Parboiled Handpounded vs Parboiled Dehusked	2.235

* Significant at 5 per cent level
** Significant at 1 per cent level

In ADT_{27}, the protein content is maximum for the dehusked sample, followed by the hand pounded rice and the least is in the milled form. All these differences are significant. But in ASD_5, the differences between the protein contents in the milled and hand pounded samples as well as between the hand pounded and dehusked samples are significant.

In both raw and parboiled rice of both the strains, the difference in protein content between the milled and hand pounded samples and between milled and dehusked samples were highly significant.

These findings that the new hybrid strain ADT_{27} has got a high content of protein is in agreement with Swaminathan's (1967)[123] observations that difference in nutrient content such as increase in protein content could be brought about through hybridization. This increased protein content of ADT_{27} have far reaching effects on alternating the protein shortage in our country.

C. Total Ash:

Table V gives the total ash content of the differently treated samples of rices from ADT_{27} and ASD_5.

TABLE V

TOTAL ASH CONTENT OF THE DIFFERENTLY PROCESSED RICE SAMPLES ADT_{27} AND ASD_5 (PER 100 G)

Strain of rice	Triplicates mg.	mg.	mg.	Mean mg.
ADT 27				
1. Raw Milled	0.60	0.64	0.65	0.63
2. Raw Handpounded	0.76	0.78	0.73	0.76
3. Raw Dehusked	1.28	1.20	1.18	1.22
4. Parboiled Milled	0.72	0.71	0.74	0.72
5. Parboiled Handpounded	0.90	0.92	0.91	0.91
6. Parboiled Dehusked	1.32	1.34	1.33	1.33
ASD_5				
1. Raw Milled	0.60	0.62	0.64	0.63
2. Raw Handpounded	0.95	0.89	0.87	0.90
3. Raw Dehusked	0.98	0.97	1.00	0.98
4. Parboiled Milled	0.72	0.72	0.71	0.71
5. Parboiled Handpounded	0.84	0.91	0.87	0.87
6. Parboiled Dehusked	1.02	1.11	1.07	1.06

Many investigators have reported about the total ash content in rice, as being very low at 0.6 to 1.3 g. in 100 g. of rice, whereas in other cereals like Bajra the total ash content is 2.3 - 2.7 gram in 100 g.

In this study as Table V shows, differences were notic ed in the total ash content of the two strains of rice, in which ADT_{27} has higher amounts than ASD_5. In both the strains of rice parboiling, hand pounding and dehusking have increased the total ash content, as compared to the raw milled samples. The increase in total ash in the parboiled samples may be due to the transfer of minerals from outer aleurone layer into the endosperm. The ash content of hand pounded and dehusked samples were found to be high because of the partial or complete presence of bran alongwith the endosperm.

D. Calcium:

That of all the cereals rice is a very poor source of calcium, Kik and Williams (1945)[15], and Swaminathan and Bhagavan (1960)[11] is shown in Table VI which gives the calcium content of samples of rice, ADT_{27} and ASD_5 obtained by different processing methods.

TABLE VI

CALCIUM CONTENT OF DIFFERENTLY PROCESSED RICE – mg/100g.

S.No.	Strain of rice	1	2	3	4	5	Mean value
	<u>ADT 27</u>						
1.	Raw Milled	28.0	27.2	28.4	27.2	27.6	27.68
2.	Raw Handpounded	30.0	29.6	31.6	27.2	29.6	29.60
3.	Raw Dehusked	38.0	38.5	37.3	38.2	38.0	38.00
4.	Parboiled Milled	28.8	29.6	32.0	30.4	29.2	30.00
5.	Parboiled Handpounded	36.0	36.8	35.2	36.8	36.4	36.24
6.	Parboiled Dehusked	44.0	43.6	46.2	44.8	43.6	44.44
	<u>ASD 5</u>						
1.	Raw Milled	14.0	15.2	16.0	14.4	14.4	14.80
2.	Raw Handpounded	20.4	21.6	22.4	20.4	20.8	21.12
3.	Raw Dehusked	28.4	30.8	28.8	27.6	29.6	29.04
4.	Parboiled Milled	19.2	20.8	21.2	19.6	20.0	20.16
5.	Parboiled Handpounded	22.0	21.6	23.2	22.0	22.0	22.16
6.	Parboiled Dehusked	35.6	36.4	34.8	35.2	36.0	35.60

Table VI shows that ADT_{27} has got higher amounts of calcium as compared to ASD_5 regardless of the processing. The hand pounding and dehusking result in considerable calcium retention in the rice. In this, these dehusking appears to exert the maximum influence. Ranganathan _et al_ (1938)[111] stated that parboiling increased the calcium content of rice. Similar effect of parboiling is seen in this study when the calcium content parboiled and raw rice of ADT_{27} are compared.

E. Phosphorous:

Table VII gives the phosphorous content of the differently processed rice samples.

TABLE VII

PHOSPHOROUS CONTENT OF DIFFERENTLY PROCESSED RICE mg/100g.

S.No	Samples	Replicates 1	2	3	4	Mean Value
	ADT 27					
1.	Raw Milled	188	179	188	187	185
2.	Raw Handpounded	221	220	224	200	216
3.	Raw Dehusked	300	305	306	304	304
4.	Parboiled Milled	186	190	176	172	181
5.	Parboiled Handpounded	250	243	248	256	249
6.	Parboiled Dehusked	335	320	327	330	328
	ASD 5					
1.	Raw Milled	165	160	158	160	161
2.	Raw Handpounded	202	206	205	214	208
3.	Raw Dehusked	270	273	284	281	277
4.	Parboiled Milled	143	146	150	152	148
5.	Parboiled Handpounded	214	217	220	212	216
6.	Parboiled Dehusked	283	285	290	288	286

As stated by Subrahmanyan et al (1938)[92] parboiling has resulted in the transfer of the phosphorous present in the germ to the endospherm, whereby there is increase in the phosphorous content.

From the table VII, it is revealed that there was no difference in phosphorous content between the two strains of rice namely ADT_{27} and ASD_5 and that parboiling increases the phosphorous content of rice. Joseph et al (1958)[159] state that undermilling increases the phytin phosphorous content and a higher phytin phosphorous is likely to affect adversely the utilisation of calcium. Sundararajan (1938)[63] reported on the increase in phytin-phosphorous due to the parboiling. So the higher phosphorous content obtained in the rice may be due to the presence of phytin-phosphorous, which is not desirable for calcium phosphorous utilisation.

Calcium Phosphorous Ratio:

Table VIII gives the value for calcium phosphorous ratio in the differently processed samples of rice.

TABLE VIII

CALCIUM PHOSPHOROUS RATIO OF THE DIFFERENTLY PROCESSED ADT_{27} AND ASD_5 (PER 100 G)

Samples of rice	Calcium mg.	Phosphorous mg.	Calcium Phosphorous Ratio
ADT_{27}			
Raw Milled	27.68	135	1:7
Raw Handpounded	29.60	216	1:7
Raw Dehusked	33.00	304	1:8
Parboiled Milled	30.00	181	1:6
Parboiled Handpounded	36.24	323	1:12
Parboiled Dehusked	44.44	449	1:7
ASD_5			
Raw Milled	14.30	161	1:10
Raw Handpounded	21.12	208	1:9
Raw Dehusked	29.04	277	1:5
Parboiled Milled	20.6	148	1:7
Parboiled Handpounded	22.16	213	1:9
Parboiled Dehusked	38.60	286	1:8

Kik and Williams (1945)[15] stated that in rice calcium and phosphorous are present in the ratio of 1:10, which is not desirable, as the higher phosphorous content affects the utilisation of calcium in the diet.

He has suggested 1:2 as the desirable calcium phosphorous ratio. Giri (1940)[64] and Ahmed et al (1948)[65] reported that calcium from rice and rice diets was not available completely, because of the high phytin phosphorous content (58 per cent) which in turn affected the utilisation of calcium from rice.

In the present study, in all the differently processed rice samples, the calcium and phosphorous ratio although slightly better than the figures obtained so far, is still on the undesirable side.

F. Iron:

The differently processed rice samples were analysed for the iron content and Table IX gives the replicate values of the samples for iron.

TABLE IX

IRON CONTENT OF DIFFERENTLY PROCESSED RICES ADT_{27} AND ASD_5 (MG/100 G)

S.No.	Strain of rice	Triplicates 1	2	3	Mean Value mg.
	ADT_{27}				
1.	Raw Milled	3.8	4.4	3.8	4.00
2.	Raw Handpounded	4.4	4.2	4.0	4.15
3.	Raw Dehusked	2.4	2.1	1.9	2.10
4.	Parboiled Milled	4.8	4.9	4.5	4.70
5.	Parboiled Dehusked	2.3	2.5	2.8	2.30
6.	Parboiled Handpounded	5.0	5.4	5.3	5.23
	ASD_5				
1.	Raw Milled	3.2	3.3	3.4	3.30
2.	Raw Handpounded	4.2	4.1	4.0	4.07
3.	Raw Dehusked	2.1	2.4	1.9	2.13
4.	Parboiled Milled	4.0	4.1	4.2	4.07
5.	Parboiled Dehusked	2.3	2.1	2.0	2.13
6.	Parboiled Handpounded	4.9	4.6	4.7	4.73

It is evident from the table IX that the values for iron content, ranges from 2.1 mg. in raw dehusked sample of ADT_{27} rice to 5.2 mg. per cent for the parboiled hand pounded sample of the same strain. The same effect is seen in the local strain ASD_5, in which case, the raw dehusked sample has the lowest iron content, and the parboiled and hand pounded sample has the higher amounts comparatively.

The iron content is not significantly different in the strains of rice. In general parboiling and hand pounding increase the total iron content. Though parboiling increases the total iron content; according to Ranganathan (1938)[111] ~~who stated that~~ the available iron from the parboiled rice is comparatively lower than the raw rice.

From Table ~~VII~~ IX, it is further shown that among the differently processed rice, hand pounded samples of rice has higher iron content, which is suspected to be due to the iron ring attached to the pestle used for pounding the paddy in the present study. In general, foods cooked in iron vessels contain higher amounts of iron, but how far the pestle used in the present study for pounding paddy had any effect on the total iron content needs to be verified.

G. Thiamine:

Table X gives the thiamine content of ~~of~~ the rice samples.

TABLE X

THIAMINE CONTENT OF DIFFERENTLY PROCESSED ADT_{27} AND ASD_5

S.No.	Strain of rice	Sample I mg.	Sample II mg.	Mean Value mg.
	ADT_{27}			
1.	Raw Milled	0.1315	0.1320	0.1317
2.	Raw Handpounded	0.2342	0.2310	0.2326
3.	Raw Dehusked	0.4536	0.4530	0.4533
4.	Parboiled Milled	0.1710	0.1714	0.1712
5.	Parboiled Handpounded	0.3416	0.3416	0.3416
6.	Parboiled Dehusked	0.4736	0.4740	0.4735
	ASD_5			
1.	Raw Milled	0.1050	0.1058	0.1054
2.	Raw Dehusked	0.4210	0.4213	0.4214
3.	Raw Handpounded	0.2372	0.2394	0.2383
4.	Parboiled Milled	0.1705	0.1716	0.1710
5.	Parboiled Dehusked	0.4473	0.4486	0.4479
6.	Parboiled Handpounded	0.3412	0.3418	0.3415

Kik and Williams (1945)[15] and Hinton (1948)[94] reported that parboiling increased the thiamine content of rice in which the endosperm after parboiling is enriched with the nutrient. Swaminathan (1946)[160] reported that parboiling increased the thiamine content two to three times more than the raw samples.

It is evident in this study also that parboiling results in appreciable increase in thiamine content.

From the table X it can be seen, that the thiamine content is not affected by or strain difference as there is not much difference in the thiamine content between ADT_{27} and ASD_{8}.

Banerjee and Guha (1955)[161] analysed different varieties of rice to find out the difference between strains for thiamine content. Their study revealed that there was no marked differences between the strain for thiamine content.

Hand pounding and dehusking also have beneficial effects on the thiamine content of rice. Swaminathan and Bhagavan (1960)[11] also state that hand pounded and dehusked samples are richer in thiamine content, when compared with milled polished samples of rice.

Table X shows also an appreciable increase in the thiamine content in both the strains due to hand pounding and dehusking. This is because the pericarp and germ which are rich in thiamine are present partially in hand pounded rice and completely present in dehusked rice. But in the commercial milling and polishing process the germ and peri carp are completely removed, lowering the thiamine content. The Nutrition Committee for the

South and East Asia (1956)[162] stated that milling results in loss of thiamine ranging from 50 to 75 per cent. Confirming their view in this study also milled sample showed the lowest value for thiamine.

V SUMMARY AND CONCLUSION

ADT_{27} which is one of the high yielding strains of paddy was processed by parboiling, milling, hand-pounding and dehusking and the samples of the resulting rice were analysed for nutritive value and compared with a local strains of paddy, ASD_{5}.

The procedures for the different processes were standardized for both the strains of paddy. The nutrient analysed included calories, protein, total ash, calcium, phosphorous, iron and thiamine.

The findings of the study are:-

1) The hybrid strain ADT_{27} proved to be significantly superior to ASD_{5} with regard to calories, protein and calcium contents. The new hybrid variety ADT_{27} was found to contain protein in higher concentration, 12 g. per 100 g. which is higher than 6 to 8 g. per 100 g. reported by Aykroyd at al (1966)[20].

2) Parboiling effected an increase in the protein content of both the strains significantly.

3) Dehusked rice had the highest values for calories, protein, calcium, phosphorous,

iron and thiamine. Next to dehusking, hand-pounding results in the retention of nutrients. Milled rice acquired the least retention of any of the nutrients.

Because of the higher protein and caloric contents it is concluded that ADT_{27} rice has great potential for solving the calorie-protein shortages in our country.

If ADT_{27} is parboiled, dehusked or handpounded, higher amounts of nutrients will be retained thus increasing further the nutritive benefits of ADT_{27}.

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APPENDICES

APPENDIX I

CALORIC CONTENT G/100g. OF DIFFERENTLY PROCESSED RICE SAMPLES

S.No.	Samples	A	B	C	Mean value
	ADT 27				
1.	Raw Milled	387	374	370	377
2.	Raw Handpounded	398	390	380	391
3.	Raw Dehusked	412	410	404	408
4.	Parboiled Milled	388	376	380	381
5.	Parboiled Hand pounded	395	390	391	392
6.	Parboiled Dehusked	414	418	421	418
	ASD 5				
1.	Raw Milled	335	339	341	338
2.	Raw Handpounded	360	362	361	361
3.	Raw Dehusked	394	399	384	392
4.	Parboiled Milled	340	342	346	343
5.	Parboiled Handpounded	365	364	371	366
6.	Parboiled Dehusked	392	398	390	393

APPENDIX II

't' VALUE CALCULATION FOR RAW RICE SAMPLES-ADT_{37} AND ASD_5 FOR CALORIES

Strain of rice	Raw Rice			Standard Error	't' value
	Milled	Hand Pounded	Dehusked		
ADT_{37}	377	391	409	387 ± 36.8	
					3.033**
ASD_5	339	361	392	363.6 ± 8.10 ~~3.19~~	

ADT_{37} Raw Rice Vs ASD_5 Raw Rice:

Standard Error was calculated as follows:

$$\text{Standard Error} = x = \frac{s}{\sqrt{n}}$$

$$s = \sqrt{\frac{\Sigma xi^2 - (\Sigma xi)^2/n}{(n-1)}}$$

For Example

S. No.	xi	xi²
1.	397	140769
2.	374	139876
3.	370	136900
4.	412	167444
5.	410	168100
6.	404	163216
7.	399	159404
8.	390	152100
9.	380	152331
Total	3525	1383500

Where n = 9

$$x = \frac{\Sigma xi}{n} = \frac{3525}{9} = 391.6$$

$$(\Sigma xi)^2 = 12430000$$

$$\Sigma xi^2 = 1383501$$

Using the above formula

$$s^2 = \frac{1383501 - \frac{12430000}{9}}{(9-1)}$$

$$= \frac{1382500 - 1381111}{8}$$

$$s^2 = 174.7$$

$$= 41.7$$

$$x = 13.9$$

contd...

Calculation of 't' values:

ADT 27 Raw Rice Vs ASD 5 Raw Rice

$$t = \frac{392 - 367}{\sqrt{\frac{197 + 530}{8}}}$$

$$= \frac{25}{\sqrt{\frac{45.4}{8}}}$$

$$t = 0.05505$$

Strain	Parboiled rice			Standard error	't' value
	Milled	Hand pounded	Dehusked		
ADT 27	331	392	418	391 ± 13.9	3.114**
ASD 5	343	366	403	363 ± 25.3	

Standard Error:

(ADT 27)

$$S = \frac{1420687 - \frac{12766329}{9}}{(9-1)}$$

$$S\bar{x} = \frac{110.5}{3} = 36.8$$

$$S = \frac{1219810 - \frac{10342864}{9}}{(9-1)}$$

$$S\bar{x} = \frac{69.2}{3} = 25.0$$

contd...

$$t = \frac{397 - 367.3}{\sqrt{\frac{277 + 431.36}{8}}}$$

$$= \frac{29.7}{\sqrt{\frac{703.36}{8}}}$$

$$t = 0.06705$$

Strain and sample		Mean	Standard error	't' value
ADT 27	Raw Rice	367	± 36.8	
	Parboiled Rice	391	± 15.9	0.01688
ASD 5	Raw Rice	363	± 8.11	
	Parboiled Rice.	392	± 23.3	0.3660

Raw Rice Vs. Parboiled Rice (ADT 27):

$$t = \frac{392 - 397}{\sqrt{\frac{197 + 277}{8}}}$$

$$= \frac{5}{\sqrt{\frac{29.63}{8}}}$$

$$t = 0.01688$$

Raw Rice Vs Parboiled Rice (ASD 5):

$$t = \frac{367 - 367.3}{\sqrt{\frac{530 + 438}{8}}}$$

$$= \frac{0.3}{\sqrt{\frac{60.5}{8}}}$$

$$t = 0.04958$$

Strain of rice (Raw and Parboiled)	Mean Value	't' value
ADT 27	394.5	4.410**
ASD 5	365	

ADT 27 Vs ASD 5:

$$t = \frac{394 - 366}{\sqrt{\frac{203.6 + 432}{17}}}$$

$$= \frac{28}{\sqrt{\frac{635.6}{17}}}$$

$$t = 4.410$$

APPENDIX III

't' VALUE CALCULATIONS FOR DIFFERENTLY PROCESSED RICE (ADT 27)- For Calories

Sample ADT 27	Mean	Standard Error	't' Value
1. Raw Milled Vs	377	± 5.09	2.432
Raw Handpounded	391	± 26.20	
2. Raw Milled Vs	377	± 5.09	4.935**
Raw Dehusked	408	± 2.30	
3. Raw Handpounded Vs	391	±26.20	6.058**
Raw Dehusked	408	± 2.30	
4. Parboiled Milled Vs	386	± 7.4	2.35[illegible]*
Parboiled Handpounded.	392	± 23.9	
5. Parboiled Milled Vs	386	± 7.4	9.065**
Parboiled Dehusked	418	± 46.2	
6. Parboiled Handpounded Vs	392	± 23.9	7.762**
Parboiled Dehusked	418	± 46.2	

Calculation of 't' Values:

Raw Milled Vs Raw Hand pounded:

$$t = \frac{377 - 391}{\sqrt{\frac{52.66 + 13.33}{2}}}$$

$$= \frac{14}{\sqrt{\frac{65.99}{2}}}$$

$$t = 2.432$$

Raw Milled Vs Raw Dehusked:

$$t = \frac{377 - 408}{\sqrt{\frac{52.66 + 12.0}{2}}}$$

$$= \frac{31}{\sqrt{\frac{64.66}{2}}}$$

$$= 4.933$$

Raw Handpounded Vs Raw Dehusked:

$$t = \frac{391 - 408}{\sqrt{\frac{13.33 + 12.0}{2}}}$$

$$= \frac{17}{\sqrt{\frac{35.33}{2}}}$$

$$t = 6.050$$

Parboiled Milled Vs Parboiled Handpounded:

$$t = \frac{381 - 392}{\sqrt{25.00 + 4.66}}$$

$$= \frac{11}{\sqrt{\frac{29.66}{2}}}$$

$$t = 2.856$$

Parboiled Milled Vs Parboiled Dehusked:

$$= \frac{381 - 418}{\sqrt{\frac{25.0 + 8.33}{2}}}$$

$$= \frac{37}{\sqrt{\frac{33.33}{2}}}$$

$$t = 9.065$$

Parboiled Hand pounded Vs Parboiled Dehusked:

$$t = \frac{366 - 393}{\sqrt{\frac{10.0 + 11.66}{2}}}$$

$$= \frac{27}{\sqrt{\frac{21.66}{2}}}$$

$$t = 2.595$$

't' VALUE CALCULATION FOR DIFFERENTLY PROCESSED RICE SAMPLES ASD 5 FOR CALORIES

	Sample ASD 5	Mean	Standard Error	't' Value
1	Raw Milled Vs	388	± 12.66	9.305**
	Raw Handpounded	361	± 37.96	
2.	Raw Milled Vs	388	± 12.66	10.73**
	Raw Dehusked	392	± 0.57	
3.	Raw Handpounded Vs	361	± 37.96	13.50**
	Raw Dehusked	392	± 0.57	
4.	Parboiled Milled Vs	343	± 10.51	9.305**
	Parboiled Handpounded	366	± 2.12	
5.	Parboiled Milled Vs	343	± 10.51	18.67**
	Parboiled Dehusked	393	± 2.38	
6.	Parboiled Handpounded Vs	366	± 2.12	2.595
	Parboiled Dehusked	393	± 2.38	

Calculation 't' Values:

Raw Milled Vs Raw Handpounded:

$$t = \frac{388 - 361}{\sqrt{\frac{11.66 + 0.66}{2}}}$$

$$= \frac{23}{\sqrt{\frac{12.32}{2}}}$$

$$t = 9.305$$

Raw Milled Vs Raw Dehusked:

$$t = \frac{338 - 392}{\sqrt{\frac{11.66 + 39.00}{2}}}$$

$$= \frac{54}{\sqrt{\frac{50.66}{2}}}$$

t = 10.73

Raw Hand pounded Vs Raw Dehusked:

$$t = \frac{361 - 392}{\sqrt{\frac{0.66 - 0.39}{2}}}$$

$$= \frac{31.}{\sqrt{\frac{105}{2}}}$$

t = 1350

Parboiled Milled Vs Parboiled Handpounded:

$$t = \frac{343 - 366}{\sqrt{\frac{6.33 + 10.03}{2}}}$$

$$= \frac{23}{\sqrt{\frac{16.33}{2}}}$$

t = 8052

Parboiled Milled Vs Parboiled Dehuskeds

$$t = \frac{343 - 393}{\sqrt{\frac{6.33 + 11.66}{2}}}$$

$$= \frac{50}{\sqrt{\frac{17.99}{2}}}$$

$$t = 16.67$$

Parboiled Handpounded Vs Parboiled Dehusked:

$$t = \frac{366 - 393}{\sqrt{\frac{10.0 + 11.66}{2}}}$$

$$= \frac{27}{\sqrt{\frac{21.66}{2}}}$$

$$t = 2.595$$

APPENDIX IV

PROTEIN CONTENT OF DIFFERENTLY PROCESSED RICE- g/100g.

S.No.	Strain of rice	Samples					Mean value
		1	2	3	4	5	
	ADT 27						
1.	Raw Milled	10.03	10.05	10.18	10.12	10.15	10.11
2.	Raw Dehusked	10.67	10.62	10.64	10.74	10.58	10.65
3.	Raw Handpounded	10.00	10.56	10.62	10.71	10.43	10.57
4.	Parboiled Milled	10.12	10.07	10.09	10.17	10.25	10.14
5.	Parboiled Dehusked	12.98	13.03	12.86	12.98	12.84	12.96
6.	Parboiled Handpounded	12.50	12.15	12.35	12.25	12.41	12.33
	ASD 5						
1.	Raw Milled	7.72	7.73	7.90	7.35	7.63	7.70
2.	Raw Dehusked	8.20	8.41	8.26	8.34	8.21	8.28
3.	Raw Handpounded	7.84	8.02	7.78	7.91	7.77	7.86
4.	Parboiled Milled	7.78	7.96	7.98	7.69	7.62	7.80
5.	Parboiled Dehusked	9.32	9.38	9.32	9.41	9.39	9.36
6.	Parboiled Handpounded	9.14	8.90	9.05	9.01	9.02	9.02

APPENDIX V

't' VALUE CALCULATIONS FOR RAW RICE SAMPLES - ADT_{27} AND ASD_5 FOR PROTEIN

Strain of rice	Raw Rice			Standard Error	't' Value
	Milled	Hand Pounded	Dehusked		
ADT_{27}	10.11	10.57	10.65	10.44 ± 0.06 ~~0.62~~	7.721**
ASD_5	7.77	7.86	8.23	7.97 ± 0.21 ~~0.218~~	

Standard Error:

ADT_{27}

$$S = \frac{1637.87 - \frac{24560}{15}}{(15 - 1)}$$

$$S\bar{x} = \frac{0.2}{3.87} = 0.052$$

ASD_5

$$S = \frac{954.93 - \frac{14310}{15}}{(15 - 1)}$$

$$S\bar{x} = \frac{0.815}{3.74} = 0.218$$

Calculation 't' Value:

$$t = \frac{10.44 - 7.97}{\sqrt{\frac{0.497 + 0.0627}{14}}}$$

$$= \frac{2.47}{\sqrt{\frac{0.5597}{14}}}$$

$$t = 7.721$$

APPENDIX V (Contd.-)

Strain and Sample		Mean	Standard Error	't' Value
ADT_{27}	Raw Rice	10.44	± 0.082	3.672**
	Parboiled Rice	11.31	±	
ASD_5	Raw Rice	7.97	± 0.218	9.003**
	Parboiled Rice	3.73	±	

Calculations for 't' Values:

Raw Rice Vs. Parboiled Rice (ADT_{27})

$$t = \frac{10.44 - 11.31}{\sqrt{\frac{0.497 + 1.4527}{14}}}$$

$$= \frac{1.37}{\sqrt{\frac{1.9497}{14}}}$$

$$t = 3.672$$

Raw Rice Vs. Parboiled

$$t = \frac{7.97 - 3.73}{\sqrt{\frac{0.0927 + 0.5732}{14}}}$$

$$= \frac{0.76}{\sqrt{\frac{0.6359}{14}}}$$

$$t = 9.003$$

Strain of rice (Raw and parboiled)	~~Standard Error~~ Mean	't' Value
ADT_{27}	11.25	11.9**
ASD_5	3.35	

$$t = \frac{11.25 - 3.35}{\sqrt{\frac{1.3943 + 0.3332}{29}}}$$

$$= \frac{2.77}{\sqrt{\frac{1.7775}{29}}}$$

$$t = 11.19$$

APPENDIX VI

't' VALUE CALCULATIONS FOR DIFFERENTLY PROCESSED RICE ADT_{27} FOR PROTEIN

Sample ADT_{27}	Mean	Standard Error	't' Value
1. Raw Milled vs Raw Handpounded	10.11 10.57	± 0.50 ± 0.11	3.964**
2. Raw Milled vs Raw Dehusked	10.11 10.65	± 0.50 ± 0.06	12.55**
3. Raw Handpounded vs Raw Dehusked	10.57 10.65	± 0.11 ± 0.05	5.358**
4. Parboiled Milled vs Parboiled Handpounded	10.14 12.33	± 0.19 ± 0.36	31.67**
5. Parboiled Milled vs Parboiled Dehusked	10.14 12.96	± 0.19 ± 0.20	5.320**
6. Parboiled Handpounded vs Parboiled Dehusked	12.33 12.96	± 0.35 ± 0.20	4.095**

<u>Standard Error</u>:

Raw Milled

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

$$S^2 = \frac{506.03 - \frac{2550.25}{5}}{(5-1)} = \frac{506.03 - 310.05}{5}$$

$$S^2 = 14.02$$

$$S\bar{x} = \frac{1.005}{2.000} = 0.5$$

Standard Error = 0.5

Based on this calculations other standard errors were calculated

Raw Handpounded:

$$S = \frac{553.51 - \frac{273784}{5}}{(5-1)}$$

$$Sx = .2236$$

$$= \frac{.2236}{2} = 0.11$$

Raw Dehusked:

$$S = \frac{561.32 - \frac{2330.24}{5}}{(5-1)}$$

$$S^2 = 4.23$$

$$S = 1.06$$

$$S\bar{x} = \frac{1.000}{2.000} = 0.05$$

Parboiled Milled:

$$S = \frac{503.03 - \frac{2570.49}{5}}{(5-1)}$$

$$S\bar{x} = \frac{.3372}{2.000} = 0.19$$

Parboiled Handpounded:

$$S = \frac{763.90 - \frac{3306.32}{5}}{(5-1)}$$

$$S\bar{x} = \frac{0.7374}{2.236} = 0.352$$

Parboiled Dehusked:

$$S = \frac{834.010 - \frac{4173.16}{5}}{(5-1)}$$

$$S\bar{x} = \frac{0.4000}{2.000} = 0.2000$$

<u>Calculation of 't' Values:-</u> (ADT_{27})

Raw Milled vs Raw Handpounded:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{3\bar{x}_1 - \bar{x}_2}$$

Where $\bar{x}_1$ and $\bar{x}_2$ are the mean of the two samples to be compared.

$3\bar{x}1$ and $\bar{x}_2$ are the square of the standard deviation of the samples.

$$t = \frac{10.11 - 1057}{\sqrt{\frac{.00352 + .00704}{4}}} = 0.46$$

$$= \frac{0.46}{\sqrt{\frac{.01056}{4}}} = 0.9520$$

$$t = 8.954$$

Raw Milled vs Raw Dehusked:

$$t = \frac{10.11 - 10.66}{\sqrt{\frac{.0023 + .0\ 51}{4}}}$$

$$= \frac{0.54}{\sqrt{\frac{.00135}{4}}} = 1.0933$$

$$t = 12.55$$

Raw Handpounded Vs Raw Dehusked:

$$t = \frac{10.57 - 10.65}{\sqrt{\frac{0.00704 + .0061}{4}}}$$

$$= \frac{0.08}{\sqrt{\frac{0.01214}{4}}}$$

$$t = 5.358$$

Parboiled Milled vs Parboiled Handpounded:

$$t = \frac{10.14 - 12.33}{\sqrt{\frac{.00416 + .0149}{4}}}$$

$$= \frac{2.19}{\sqrt{\frac{.01906}{4}}} = 1.5007$$

$$t = 31.67$$

Parboiled Milled vs Parboiled Dehusked:

$$t = \frac{10.14 - 12.96}{\sqrt{\frac{.00334 + .00602}{4}}}$$

$$= \frac{2.82}{\sqrt{\frac{.00234}{4}}} = 1.7656$$

$$t = 5.329$$

Parboiled Handpounded vs Parboiled Dehusked:

$$t = \frac{12.33 - 12.96}{\sqrt{\frac{0.0149 + 0.00602}{4}}}$$

$$= \frac{0.63}{\sqrt{\frac{0.00518}{4}}}$$

$$t = 4.095$$

't' VALUE CALCULATIONS FOR DIFFERENTLY PROCESSED RICE SAMPLES ASD$_5$ FOR PROTEIN

Strain and sample	Mean Value	Standard Error	't' Value
1. Raw Milled vs Raw Handpounded	7.77 7.36	± 0.366 ± 0.279	1.434
2. Raw Milled vs Raw Dehusked	7.77 8.23	± 0.366 ± 0.100	8.890**
3. Raw Handpounded vs Raw Dehusked	7.36 8.23	± 0.273 ± 0.100	2.733**
4. Parboiled Milled vs Parboiled Handpounded	7.30 9.02	± 0.210 ± 0.180	15.66**
5. Parboiled Milled vs Parboiled Dehusked	7.80 9.36	± 0.210 ± 0.141	10.61**
6. Parboiled Handpounded vs Parboiled Dehusked	9.02 9.36	± 0.210 ± 0.141	2.235

Standard Error

Raw Milled:

$$S = \frac{299.59 - \frac{1505.44}{5}}{(5-1)}$$

$$S\bar{x} = \frac{1.732}{2.000} = 0.366$$

Raw Handpounded:

$$S = \frac{306.83 - \frac{1544.49}{5}}{(5-1)}$$

$$S\bar{x} = \frac{.5476}{2.000} = 0.2738$$

Raw Dehusked:

$$S = \frac{341.17 - \frac{1713.96}{5}}{(5-1)}$$

$$S\bar{x} = \frac{.2000}{2.000} = .100$$

Parboiled Milled:

$$S = \frac{299.63 - \frac{1521.00}{5}}{(5-1)}$$

$$S\bar{x} = \frac{4.242}{2.000} = 0.21$$

Parboiled Handpounded:

$$S = \frac{407.192 - \frac{2034.0}{5}}{(5-1)}$$

$$S_{\bar{x}} = \frac{0.3605}{2.000} = .1804$$

Parboiled Dehusked:

$$S = \frac{433.44 - \frac{431.05}{5}}{(5-1)}$$

$$S_{\bar{x}} = \frac{0.2323}{2.000} = 0.141$$

Raw Milled Vs Raw Handpounded:

$$t = \frac{7.77 - 7.36}{\sqrt{\frac{.00716 + .0036}{4}}}$$

$$= \frac{0.09}{\sqrt{\frac{.01576}{4}}} = 0.1565$$

$$t = 1.434$$

Raw Milled vs Raw Dehusked:

$$t = \frac{7.77 - 3.23}{\sqrt{\frac{0.00676 + 0.00644}{4}}}$$

$$= \frac{0.51}{\sqrt{\frac{0.0305}{4}}} = 1.2421$$

$$t = 3.330$$

Raw Handpounded vs Raw Dehusked:

$$t = \frac{7.36 - 3.29}{\sqrt{\frac{.0035 - .00644}{4}}}$$

$$= \frac{0.42}{\sqrt{\frac{.00376}{4}}}$$

$$t = 2.733$$

Parboiled Milled Vs Parboiled Handpounded:

$$t = \frac{7.80 - 9.02}{\sqrt{\frac{0.01834 + 0.00596}{4}}}$$

$$= \frac{1.22}{\sqrt{0.02430}}$$

$$t = 1.434$$

Parboiled Milled Vs Parboiled Dehusked:

$$t = \frac{7.80 - 9.36}{\sqrt{\frac{0.0169 + 0.0014}{4}}}$$

$$= \frac{1.56}{\sqrt{\frac{0.0183}{4}}}$$

$$t = .06813$$

Parboiled Hand Pounded Vs Parboiled Dehusked:

$$t = \frac{9.02 - 9.36}{\sqrt{\frac{0.01834 + 0.0014}{4}}}$$

$$= \frac{0.34}{\sqrt{\frac{.01977}{4}}}$$

$$t = 2.235$$