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I. INTRODUCTION

Freedom from the scourge of hunger is the profound promise of our era for mankind. If the world is to meet this challenge of hunger, food supplies must be doubled by the year 2000 (Agency for International Development, AID, 1975). But the world food picture from today's vantage point is not encouraging. A minimum of four per cent annual increase in food production is necessary to feed the present population, the 75 million new individuals who join the world each year (Harrar, 1975).

Unrestrained population growth has been warned to be the greatest threat to human well-being. It has been estimated by Mrak (1972), Brown (1975), Singh (1975) and Pimentel et al. (1976) that by the year 2000 the world population is likely to range from 6.0 billion to 7.15 billion. By then man must find more effective ways of feeding himself regulating the population and stabilising the environments. According to Scrimshaw (1975) the world is entering a period when the relationship between food availability in low-income countries and rising population is increasingly perilous and for some countries, has already reached crisis proportions.

Fewster (1975) states that the two factors common to the diets of the people of the developing tropical world are firstly that the staple foods are in short supply and secondly that these staples are inadequately supplemented with foods of animal origin. As Aylward and Jul (1975) proclaims protein deficiency is only one aspect of a wider nutritional problem and that national policies should aim at adequate supplies of energy foods and adequate supplies of all protective and body building foods.

India's food and nutrition problems today continue to be formidable, and what lies ahead for large numbers of her people is a grim struggle for mere survival (Gopalan, 1975; Baig, 1975). Gopalan (1976) points out that at the moment, the national agricultural programme is quantity-oriented, without any reference to qualitative aspects of the nutritional needs. It is lopsided and biased in favour of producing more cereals. In this opinion, the entire agricultural productive programme right from seed sowing to post harvesting, including storage and distribution, should be streamlined to meet the total food needs of the community with proper balance between cereals, vegetables and legumes.

Malnutrition is one of the major public health problems in India (Devadas, 1974; Ramalingaswami, 1975; Indira Gandhi, 1976). Long term consequences of malnutrition during the critical phases of growth and development on the physical, mental and allround development of children has been well recognised (Berg, 1973; Srikantia, 1975; Bengoa, 1975; Singh, 1976). According to Swaminathan (1976) the major nutrition problem in India is inadequacy of calories in the diet of the economically handicapped. The mean per capita consumption of protein and calorie in India are 55 g. and 1985 calories respectively (ICMR, 1971). Sukhatme (1971), FAO (1975) have estimated that in Asia, cereals provide 70 per cent of the calories and 60 per cent of the protein in the diet. However as Gopalan (1974) opines in majority of the developing countries the food contained negligible amount of good quality proteins.

Increasing the consumption of good quality protein of animal origin is beyond the scope of the common consumer, because of insufficient production and low purchasing power (Satyanarayana, 1971 and Raper, 1974). Hence the utilisation of inexpensive and indigenous protein rich sources in proper combinations will help to bridge the protein lack in developing non-conventional, semi-conventional, inexpensive, locally available, acceptable foods.

Literature points out that although the biological value of the pulse protein is lower than that of animal protein, the former help substantially in fulfilling human requirements when combined with other proteins in a mixed diet (Protein Advisory Group, PAG, 1975).

Millets like ragi and jowar are grown abundantly in India and widely consumed by the poor in certain regions of the country (NIN, 1973). The proteins in cereals and millets in general are limiting in essential amino acids, lysine being the first limiting amino acid. These amino acid deficits can be complemented by legumes which are rich not only in lysine but also threonine (Swaminathan et al. 1975).

Much headway has been made in many of the food and nutrition laboratories in India in the formulation of vegetable protein mixtures and new vistas conquered by the introduction of hybrid varieties of food grains. However to make these economically feasible and widely acceptable, as pointed out by Devadas (1967), (1973) Roberts, (1975) Sukhatme (1972) and Gopalan (1972), (1974) these mixtures should be made to supplement the customary diets by locally produced low cost nutritious and acceptable foods based on blends of cereals, oilseed meals and legumes. Self-

sufficiency alone is the surest way to wipe out malnutrition, warns Gopalan (1973), and a right step towards this self-sufficiency is to solve the local problem of malnutrition with locally available foods. This approach may lack the glamour associated with expensive, elaborate and sophisticated processing, but in the longrun may prove more rewarding and yield more tangible results in our country-side. This investigation is planned along these lines.

Ragi is one of the cereals widely consumed by the economically handicapped around Coimbatore district. This study aims at evaluating the supplementary value of selected mixtures of plant proteins in the ragi based diet. The local ragi diet was supplemented with suitable combinations of sweet potato, horse-gram, sesame, groundnut and green leafy vegetables to enhance its nutritive value and the protein quality of these ragi-based vegetable diet mixtures evaluated on albino rats.

II. REVIEW OF LITERATURE

The literature pertaining to this investigation on the biological evaluation of a ragi based diet is reviewed as follows:

- A. Malnutrition and its outcomes.
- B. Role of indigenous food mixtures in combating protein energy malnutrition.
- C. Evaluation of protein quality.

A. Malnutrition and its outcomes:

Good nutrition and malnutrition are the end of many interacting factors operating simultaneously and concurrently on the individual in the physical, ecological and cultural environment of the community (Devadas, 1972).

A large number of diet and nutrition surveys in our country have shown that the diets consumed by a large majority of the population consist predominantly of cereals and small amount of legumes and vegetables (Swaminathan, 1975). Protein-Calorie Malnutrition (PCM) affecting young growing children between the ages of 1 to 5 years is one of the important nutritional problems in India today (Swaminathan, 1969; Achaya, 1967; Mahalanabis et al: 1969; Srikantia, 1969; Swasth Hind, 1970; Pasricha, 1973 and Vinodini Reddy, 1974).

According to Gopalan (1975), in India on the basis of the incidence of growth failure, the prevalence of PCM is 80 per cent, whereas that of kwashiorkor as low as 1.2 per cent. In a malnourished community roughly 1 to 1.5 per cent of children below five years show evidence of kwashiorkor, about two to three per cent frank marasmus and the rest growth retardation and emaciation.

Malnutrition is an important cause of infant and child mortality, stunted physical growth, low work output, premature ageing and reduced span of life in the developing countries (Jelliffe, 1968; Read, 1968; Mayer, 1970; Dumo, 1971 and Oberoi, 1972). Protein malnutrition is the biggest single factor contributing to infant and young child mortality in developing countries where 25 to 30 per cent die before the age of five (Chow, et al. 1967; Berg, 1970; Subramaniam, 1971; Allan, 1972; Madhav, et al. 1973 and Devadas et al. 1974).

The relatively high prevalence of infections like cough, cold, measles and diarrhoea are usually important contributors to malnutrition (Morley and McWilliam, 1961; Scrimshaw et al. 1961 and Gorden et al. 1965). Malnutrition almost invariably lowers resistance to infection and infectious diseases

exaggerate the effects of malnutrition (Bengoa, 1970; Scrimshaw, 1972 and Gopalan, 1973). Esh (1971), Swaminathan (1970), McCance (1971), Srikantia and Yogananda Sastri (1971), Gopalan (1972), Devadas (1973), Raju (1974) and Jelliffe (1976) point out that protein - calorie malnutrition in early childhood retards growth and reduces the capacity of the child to understand and learn.

Children of the low income families do not get adequate diet at home, hence it has been found that their growth is sub optimal (FAO, 1964; Srikantia, 1971; Boerma, 1971; Agarwal et al. 1971; Bengoa, 1975 and Reddy, 1976). Even the pregnant women, especially those of the lower socio economic groups, subsist on diet which fall short of recommended allowances (Hasan, 1968; Rao, 1975 and Reddy, 1976).

Gopalan and Narasingha Rao (1971) have revealed that the daily protein intake of Indian preschoolers range from 1.7 g/kg to 2.8 g/kg body weight and daily Calorie intake was as low as 70 to 75 calories/kg body weight. The inadequacies in Indian dietaries are not only quantitative but also qualitative leading to high incidence of under-nutrition and malnutrition (Gopalan, 1971; Gupta, 1971 and Belavady, 1975).

The cereal crisis and malnutrition are interconnected. In widely dispersed countries as Brazil, India and Tunisia, the 20 per cent of the population with lowest income has half the percapita intake of the top ten percent (Ganzin, 1975). A feature of poverty in India is the high ratio of expenditure on cereals in total food expenditures.

As the world enters the United Nations Second Development Decade a small fraction of the human race is overfed and worried about diets to last out while the vast majority of mankind is either under nourished or malnourished (Michanik, 1972).

Pant (1971) and Ullrich (1970) opine that hunger and malnutrition must be attacked through a wide variety of methods. Action is particularly necessary in the struggle of freedom from hunger in extending the use of high yielding cereals (Gupta, 1971; Parpia, 1971 and Belavady, 1975), in closing the protein gap, in eliminating the waste and in mobilising the human resources (Rao, 1964; Pearson, 1970; Pyne, 1971; Pingale, 1971 and Gopalan, 1976).

For the average citizen in India according to Rao (1968) cereals provide the main source of calories (67 per cent) as well as proteins (60 per cent). Ragi and rice are the most important sources of proteins in the dietaries of the low income groups in some parts

of India (FAO, 1970). Legumes are consumed in varying amounts and will add about one to four per cent extra proteins in the poor rice and ragi diets. As Gopalan (1973) points out the ultimate nutritional upliftment of our communities can only be achieved through educating the village communities to effectively utilize locally available foods for better nutrition.

B. Role of indigenous food mixtures in combating protein energy malnutrition:

(In the last twenty years, total and percapita food production throughout the world has been steadily increasing. Despite these increase many in the developing and the developed world are poorly nourished because of poverty, poor food distribution and traditional eating habits (West, 1974 and Brown et al. 1975).

Modern science and technology has made possible the production of various processed protein foods as a measure to meet the protein deficiency. Some of the protein rich foods developed in India are the multi-purpose food, malt foods, vegetable milk, cotton seed meal, vegetable protein mixtures, fish protein concentrate and leaf protein (Devadas et al. 1975). Much work is being done in the field of protein nutrition. Research is going on to find the appropriate inexpensive sources of protein to enhance the nutritional value of the diets of the economically worser section of the society.

Pasricha et al. (1973) state that one of the most important reasons for using locally available foods in any supplementary feeding programme is that it introduces an element of self-generation. Kymal (1973) feels that the acute shortage and high cost of conventional high protein rich foods such as milk, meat, eggs etc. have necessitated the development of nutritious processed food formulations based on readily and locally available cereals, fortified with high protein edible oilseed meals and also pulses whenever readily available.

The consumption of pulses among the poor is not adequate. They rely mostly on cereals for their ✓ proteins and calories (Belavady, 1975). Hence there is need to develop blends of cereals and pulses which will possess high Protein Efficiency Ratio and will meet the protein needs of malnourished children (Daniel et al. 1969). Most of the low cost vegetable protein mixtures have been prepared by using flours and concentrates making it possible to maintain the cost of the final product nearer to the staple food price (Gupta, 1972).

The supplementary relations between the proteins of rice and ragi and Bengal gram feed in the ratio of 7:3 have been studied by Patwardhan et al. (1960). A

feeding trial was conducted on weaned infants by Daniel (1967) with low cost balanced foods based on blends of ragi or maize, groundnut, Bengal gram, soya and sesame flour and fortified with limiting amino acid. Desai et al. (1968) studied diets based on rice, ragi, wheat and sorghum supplemented with coconut meal on young rats. Coconut meal fortified with calcium salts and vitamins brought about significant increase in growth rate in the case of rice, wheat and kaffir corn diets.

Swaminathan et al. (1968) studied a diet based on ragi supplemented with protein foods based on groundnut, sesame, Bengal gram and soya flour or skim milk powder. The same study with maize showed that the growth promoting value of the maize diet was noted only when the supplement provided ten percent extra proteins. The effect of replacement of 25 per cent of the cereals in poor Indian diets with a low cost mixture containing 19.3 per cent protein based on a blend of ragi 65 per cent, peanut flour 25 per cent and chick pea flour 10 per cent fortified with calcium, phosphorus and vitamins on the overall value of the diets resulted in significant increases in growth of children (Kurien et al. 1970).

Radhakrishnan et al. (1963) studied the effect of the wheat based and the rice based diets on the growth of preschoolers. There was greater increase in height in group consuming rice - based diets.

Parpia et al. (1969) studied the effect of calorie restriction on the supplementary value of protein foods to poor vegetarian diets. The supplementary value of a protein food (Indian Multipurpose food) based on 3:1 blend of peanut and chick pea flours fortified with minerals and vitamins to poor vegetarian diets based on rice and ragi under conditions of adequate and inadequate calorie intakes on albino rats.

Supplementing a rice based diet with 50 g of edible groundnut flour, fortified with vitamins and minerals, had a significant higher nitrogen retention than rice diets according to Parthasarathy et al. (1962). Patel et al. (1970) evaluated diets of jowar flour containing flour to provide seven per cent proteins and mixtures of jowar flour with ambadi and methi to provide five per cent from jowar and two per cent protein from the leafy vegetables. The PER of the diets were found to be 0.92, 0.94 and 1.54 respectively. Rajalakshmi (1975) studied the effect of different supplements to maize and jowar on the

protein and niacin status of weanling rats. Mixtures of maize, green gram and groundnut and maize, Bengal gram and groundnut were evaluated for protein quality through albino rats. The protein quality of the maize, Bengal gram and groundnut mixture equalled that of skim milk and the other was almost as efficient according to Easwaran et al. (1972).

Devadas et al. (1974) evaluated a weaning mixture based on locally available cereals and pulses such as maize, roasted Bengal gram dhal, roasted groundnut and jaggery. A significant increase was seen in the heights and weights of children in the experimental group.

Green gram was found to be a good supplement to cereals for it has a very good supply of the essential amino acid through the studies conducted by Deshmukh and Sohnie, (1965). Eapen et al. (1968) have found out that a combination of red gram dhal and skim milk in the protein ratio 1:1 could be an efficient substitute for an equal quantity by protein content of skim milk or to a combination of the multipurpose food and skim milk.

Groundnuts are a potential source of supplementary protein for human food. They contain a fair

amount of protein. Their products have found wide acceptance as food throughout the world (Rhee, 1972). Carpenter et al. (1968) fed groundnut and lysine to young rats at a high level as their sole source of protein. It supported weight gain and nitrogen retention equal to that of egg protein. According to Krishnamoorthy et al. (1960), protein foods based on blends of groundnut, Soyabean and sesame flour with a protein content between 45 to 48 per cent when fed at 16 per cent level were as effective as skim milk in promoting growth in rats. Prasanna et al. (1969) formulated a mixture with milk, coconut and groundnut having about 26 per cent of the total proteins, one-fifth from milk and two-fifth from groundnut.

Research efforts in several countries have helped to develop high protein mixtures of locally available plant material that approach or equal the results obtained with milk proteins. The main protein sources for such combinations are cereals, legume seeds, oil seeds and meals and isolated plant proteins (Register et al. 1967). Tasker et al. (1960) states that the vegetable protein mixtures can be a good substitute to poor diets. Reynolds et al. (1962) and Oldham et al. (1965) found that nitrogen retention

was greater in women receiving crystalline amino acid in the peanut pattern than amino acid in the FAO pattern.

Kamalanathan et al. (1970) obtained significant improvement in the nutritional status of pre-school children who were fed supplements of groundnut meal, sesame, horsegram in the ratio 2:2:1. Studies carried out by Central Food Technological Research Institute have shown that supplementation of the diets of children with fortified protein foods based on blends of groundnut, coconut and sesame flours made up the deficiencies in the diet and promoted good growth in children (Doraiswamy et al., 1959). Lyon (1972) fed rats with a ten percent protein ration for four weeks fortified with lysine to a level of 4.2 per cent and raised the PER from 1.7 to 2.14, fortification with lysine to a level of 8.2 per cent raised the PER to 2.9. CSM, Balahar, leaf protein and skim milk diets at ten per cent level were made isocaloric by adjusting the fat content of the protein sources. The PER values obtained were as follows CSM 3.81, skim milk 3.26, Leaf Protein 2.19 and Balahar 1.99 (Chandrasekhar, et al. 1975). Allan (1972) speaks of the post

kwashiorkor food mixture which consisted of 40 per cent corn flour meal, 38 per cent full fat soya flour, 15 per cent sugar, 5 per cent dry skim milk and 2 per cent vitamin-mineral mixture.

The availability of protein and minerals from red hake was studied under constant and controlled dietary conditions. The fish protein concentrate supplemented diet was well tolerated by the subjects (Spencer et al. 1971).

Research studies conducted by scientists and others interested in food technology and nutrition have helped in the formulation of many nutritionally rich protein mixtures which could help to solve the protein famine.

C. Evaluation of protein quality:

The need of any single species for a specific nutrient such as protein can be defined by an infinite numbers of variables. Based on the factors which alter protein needs different methods have been developed for evaluating dietary protein (FAO, 1965). McLaughlan and Campbell (1970) state that the protein evaluation methods are necessary in order to be able to rank the proteins in order of their efficiency under standard conditions and secondly, to compare the efficiency of different sources of proteins to meet the nitrogen and amino acid requirements.

Evaluating the nutritive quality of dietary protein involves measurement of several parameters utilising appropriate methods. The determination of biological value and PER are the traditional methods (Thomas, 1909; Osborne et al. 1919; Mitchell, 1924 and Mitchell and Carmen, 1926). The efficiency with which a protein is used for growth and maintenance is a measure of its quality (Blender, 1954; NRC, 1963; Watts, 1965 and Bhat et al. 1974).

1. Methods of evaluation of protein quality:

The two procedures that are used for evaluating the protein quality are the indices based on (a) weight gain and (b) body nitrogen changes (NRC, 1963).

Venkat Rao et al. (1964) classify the methods available for evaluation of the protein quality as those based on growth of the body. Carcass nitrogen analysis, nitrogen balance studies, regeneration of blood and liver constituents, determination of the availability of amino acids, chemical scoring and miscellaneous methods.

The quality of protein obtained from a diet depends on the amount of food consumed and on the protein content of the food (Sood et al. 1974). Lekin (1973) emphasises the fact that the protein quality may also be affected by the stages of growth, infection,

physiological condition, gastro-intestinal disorders and stress. Various methods available for evaluation of the protein quality has been extensively reviewed by several workers (Bender, 1975). The methods received here pertain to that of body growth, nitrogen balance studies and carcass nitrogen.

a. Methods based on growth of body:

(i) Protein Efficiency Ratio (PER):

Protein Efficiency Ratio is the increase in the body weight in grams to the protein consumed (Beaton and McHenry, 1964 and Allison et al. 1964). PER is based solely on the gain in body weight and does not take into account the composition of weight increment (NRC, 1963).

The NRC (1963) enumerates the favourable conditions for PER determinations as a four week assay period, diets containing ten per cent protein and providing all other essential nutrients, male weanling rats and ad libitum feeding.

Growth is perhaps the earliest of the parameters used in nutritional evaluation of the protein. As early as 1919, Osborne and his co-workers showed that the rate of growth of weanling rats under standard condition provided a reliable measure of the value of dietary protein (Campbell, 1961).

For good quality protein, the PER values decreased markedly as the protein content of the diet increased, whereas in the case of poor quality protein there was some increase in the PER followed by a decrease (Henry and Kon, 1958 and Rao et al. 1963).

Muramatsu and Ashida (1962) found that the response curve of changes in turn over rate of body proteins plotted against protein intake at different levels was similar to that of body weight plotted in a similar way. Hegsted and Worcester (1947) observed that there was a very high correlation between gain in weight and protein efficiency. Sibbald et al. (1957) noted that variations in the food consumption of weanling rats, fed rations containing varying nitrogen sources, were largely associated with the apparent digestible energy content of the rations.

(ii) Net Protein Ratio (NPR):

The method was introduced first by Bender and Doel (1957). It is a modification of PER methods and the experimental period is ten days. By including one additional group on protein free diet to make an allowance for the protein requirement for maintenance, the net protein ratio is calculated.

$$\text{NPR} = \frac{\text{Weight gain by test group (g)} + \text{Weight loss of protein free group (g)}}{\text{Protein intake of test groups in grams}}$$

(McLaughlan, 1972).

As in the case of PER, NPR is also influenced by protein of the diet.

(iii) Gross Protein Value: (GPV)

Gross protein value was first suggested by Heiman et al (1939) and later modified by Carpenter (1957). The gross protein value of supplementary protein is calculated as the extra growth obtained with the supplementary protein eaten. This is expressed as the percentage of the corresponding figure obtained with casein as the test supplement.

(iv) Nitrogen Growth Index:

When the nitrogen is fed at different levels and plotted against gain in body weight over a period of 28 days, a curve is obtained. The slope of the curve has been called the nitrogen growth indices (Venkata Rao et al. 1964). Evaluating the standard rat assays in assessing the protein quality of foods, McLaughlan (1974) opines that the slope method is the most suited in that it has the advantages of the slope ratio assay and would give a truly predictive value for lysine deficient diets.

(b) Methods based on nitrogen balance:(i) Biological Value:

The biological value is determined by the nitrogen balance which is defined by the ratio of nitrogen retained and nitrogen absorbed (NRC, 1963). From this the following formula for digestibility and biological value have been worked out by Mitchell and Co-workers.

$$\text{Digestibility} = \frac{\text{Nitrogen consumed} - \text{faecal N}_2 + \text{Metabolic N}_2}{\text{N}_2 \text{ absorbed}}$$

Where metabolic N₂ = faecal N₂ output on a protein diet - Protein free diet.

$$\text{Biological Value} = \frac{\text{N}_2 \text{ absorbed} - \text{Urinary N}_2 + \text{endogenous N}_2}{\text{N}_2 \text{ absorbed}}$$

The protein to be tested has to be fed to the animal as the sole source of nitrogen in the diet. The measured urinary and faecal nitrogen must be corrected by subtracting the quantities that would be lost on a protein free diet. The biological value makes no allowance for losses of nitrogen in digestion (Allison, 1964).

The formula for the biological value can also be written as:

$$\frac{\text{Retained Nitrogen}}{\text{Absorbed Nitrogen}} \times 100$$

Nitrogen balance studies depends upon the concentration of protein, nitrogen intake and the energy intake (Calloway, 1955).

(ii) Digestibility Co-efficient:

The digestibility co-efficient of a protein may be obtained by using the equation suggested by Platt et al. (1961). This is an important aspect of the nitrogen balance studies.

$$\text{Digestibility Co-efficient} = \frac{\text{N}_2 \text{ intake} - (\text{faecal Nitrogen} - \text{endogenous faecal nitrogen})}{\text{Nitrogen intake}} \times 100$$

Where faecal N_2 is the nitrogen excreted in the faeces during the test diet and the endogenous nitrogen is the amount excreted in the faeces when a protein free diet is fed.

(c) Methods based on carcass nitrogen analysis:

(i) Net Protein Utilisation:

Miller and Bender (1955) developed a direct method of evaluating protein quality and termed it as Net Protein Utilisation.

NPU is the most used method. This is the proportion of ingested nitrogen that is retained in the body under specific conditions. NPU is a combined measure of digestibility and of the efficiency of utilisation of absorbed amino acid.

$$\text{NPU} = \frac{\text{Body N}_2 \text{ of the test group (BF)} - \text{Body N}_2 \text{ of non-protein group (BK)} + \text{N}_2 \text{ consumed by non-protein group (IK)}}{\text{N}_2 \text{ consumed by test group}} \times 100$$

(Chalupa and Fisher, 1963)

The experimental procedure is as follows: One group of rat is fed protein free diet, and the rest the test diet at ten per cent level for ten days and the carcass is dried for forty eight hours at 104°C. The nitrogen is estimated by the Kjeldahl method by using the above formula.

(ii) NDp Calories percent:

The carcass analysis method is a direct method of measuring the nitrogen retained for growth and maintenance applicable only to experimental animals (Watt, 1965).

The efficiency of the concentration of protein when expressed in terms of calorific value of the diet is called Net Dietary protein calories percent. This criterion takes into account both protein quality and concentration. Protein quality is expressed as NPU and protein concentration as the percentage of calories in the diet supplied by proteins.

$$\begin{aligned} \text{NDP Calories\%} &= \frac{\text{Retained Protein (K Cal)}}{\text{Total metabolisable energy in food consumed.}} \\ &= \frac{\text{Retained N (g)} \times 6.25 \times 4 \text{ Kcal}}{\text{Total food intake (g)} \times (\text{Kcal/g food})} \end{aligned}$$

d. Other methods of protein evaluation:

Mitchell and Block provided a reasonable method for the chemical evaluation of protein based on their amino acid contents. The Chemical Scores was taken as the lowest egg ratio (i.e.) hundred minus the greatest percentage deficit of an essential amino acid relative to that percent in the egg protein. The protein score proposed by the 1963 Joint FAO/WHO Expert Group can also be used.

Beaton and McHenry (1964) formulated the chemical scoring method for assessing the nutritive value of food protein. Many studies have confirmed the general validity and utility of chemical methods for evaluating the potential nutritive value of a protein source for humans (Block and Mitchell, 1946; FAO/WHO, 1973; Bender, 1973 and Mauron, 1973). There is generally good correlation between the prediction of the nutritional value of unprocessed cereal protein sources based on chemical evaluation and the nutritional value determined by the bioassay procedures (Mitchell, 1946).

Chromatographic analysis of the amino acids have found great favour (Blackbury, 1968).

Enzymatic and microbial assays have been suggested to determine the availability of amino acids. Microbiological assays are more effective in the determination of the various amino acids (Rao et al. 1965 and Ferrando et al. 1968).

Arroyave (1975) suggests the protein quality index, a ratio based on the requirement of protein for age to that of the amount of test protein required to satisfy the most limiting amino acid for the subject and seems to be a more rational way, as an approach to prevent protein calorie malnutrition.

III. EXPERIMENTAL PROCEDURE

This study was planned to evaluate biologically the protein quality of ragi based diet mixtures on albino rats. The experimental procedure consisted of the following phases:

- A. Formulation of the ragi based diet mixtures.
- B. Preparation of the diet mixtures.
- C. Selection and grouping of the animals.
- D. Evaluation of protein quality.

A. Formulation of the ragi based diet mixtures:

1. Basal diet:

Results of diet surveys conducted by Devadas et al. (1973) in Coimbatore district indicated that the local dietaries of the population groups where ragi was the staple food was inadequate in other essential foods. This dietary pattern hereafter mentioned as the basal diet or diet mixture 'I' was selected as one of the diets to be evaluated in this study because it was against this diet that the improvements have been worked out. The details of the basal diet is given in Table I.

TABLE I
COMPOSITION OF THE BASAL DIET

Foods	Quantity g.
Cereals	68.84
<u>Other Ingredients:</u>	
Pulses ..	7.46
Green leafy vegetables ..	3.09
Roots and tubers ..	4.22
Other vegetables ..	4.87
Fruits ..	1.52
Milk ..	7.88
Sugar and jaggery ..	1.29
Groundnut oil ..	0.83
Total	100.00

2. Experimental diets:

The ragi diet being consumed by the local people was found to be very low in protein, the content being 8.04 g/100g of the diet. The experimental diet mixtures were aimed to fill in the dietary gap of basal diet, with low cost locally available foods and to make the pattern adequate.

Devadas et al. (1973) have formulated several ragi based diet mixtures around the basal diet using low-cost locally available foods like sweet potato (root vegetable), horse gram (pulse), sesame, groundnut and cottonseed flour (oil seeds), amaranthus (green leafy vegetables).

Their aim was to enhance the nutritive value of the ragi based diet with the locally available foods and in their attempt to evaluate them biologically on albino rats, they found that ragi-based mixtures which had groundnut flour and cotton seed flour as their components, apart from the legumes, root vegetables and green leafy vegetables were adjudged to be the best in their protein quality, and calcium and vitamin 'A' retention.

However cotton seed flour is not readily available today in the market and hence in this study it was decided to evaluate another ragi based mixture which had horse gram, sesame and groundnut as their protein supplements and had an equal chemical score to that of the one containing cotton seed flour. This mixture is designated as Diet II.

To step up the nutritive value of the Diet II further, other permutations and combinations using the protein supplements sesame, groundnut and horse gram were worked out and these are presented in Appendix I.

Lyon (1972) states, sesame and its meal is a valuable supplement for food and feeds because of its high methionine content. Anantharaman (1968), Swaminathan (1969) and Oke (1975) consider groundnut as a traditional protein supplement. Horse gram a locally available legume provides equal quantity and quality of proteins at half the price when compared with other legumes.

The amino acid pattern and the chemical score of the twelve diet formulations thus worked out are given in Appendix II and III. Out of these twelve diet mixtures two mixtures which had the highest chemical scores were selected for evaluation in the study and are designated as Diets III and IV.

Thus all the four ragi-based diet mixtures formed the experimental diets in this study and the composition of these diets are given in Table II.

TABLE II

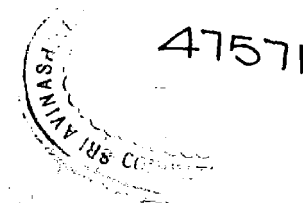
COMPOSITION OF THE RAGI-BASED DIET MIXTURES

Ingredients	Diet I	Diet II	Diet III	Diet IV
Ragi	68.84	38.84	38.59	36.84
Sweet Potato	-	5.00	5.00	5.00
Horse gram	-	11.00	8.00	8.00
Sesame	-	5.00	6.25	7.75
Amaranth	-	4.00	4.00	4.00
Groundnut	-	5.00	7.00	7.25
Other Ingredients	31.16	31.16	31.16	31.16
	100.00	100.00	100.00	100.00

In the formulation of all these diets, all the food items other than ragi in the basal diet (Table I) were kept constant since the aim was to substitute the cereal with low-cost, locally available foods. Accordingly in this investigation the term "Other ingredients" denotes all the ingredients in the basal diet other than the cereal and the low-cost substitutes.

B. Preparation of the diet mixtures:

All the foods required for the entire study were bought in one lot. The perishable foods like fruits and



vegetables were dried to a constant weight and powdered. All the other cereals and pulses were also powdered. The basal diet and the three experimental diets were mixed for the entire study and stored. For comparison, a fifth diet with skim milk at ten per cent protein was also included in the study as a standard.

To ensure an adequate supply of vitamins and minerals, mineral mixture (USP XVII) at four per cent level (Campbell, 1963) and vitamin mixture at two per cent level (Cremer, 1963) were added to the diets. The composition of the mineral and vitamin mixtures are as given in Appendix IV.

Thus all five diets were prepared for this study and were analysed in triplicates for calories in the Parr Oxygen Bomb Calorimeter (Hawk et al., 1965). Protein was analysed using the macro kjeldahl method (Hawk et al. 1965; Davidson, 1970; Mertz, 1971) and fat through the Soxhlet method (Hawk et al. 1965) and the values are as shown in Table III.

TABLE III
 CALORIE AND PROTEIN CONTENT OF THE DIETS
 (100 grams)

Diet	Calories	Protein g.
A	277	8.04
B	271	10.1
C	279	10.2
D	283	10.2
Skim milk	296	10.1

C. Selection and grouping of the animals:

Albino rats from the laboratory stock colony were selected for the different experiments based on the following criteria:

1. Twenty four day old weanling male rats were selected at the rate of ten rats per group for the five groups included in the PER experiment. The average weight in each group ranged from 31.5 g. to 31.6 g.
2. Thirty male albino rats, 100 days old (Womack, et al. 1953; Patel et al. 1970) were chosen for the nitrogen balance studies. The average weight range was 165 g to 171 g.

3. Thirty six male albino rats, twenty three days old with an average weight range between 43.7 g to 44.3 g were grouped into six groups of six animals each for the carcass analysis.

For the growth study and the carcass analysis the rats were housed in individual cages according to their groups. Specially designed metabolic cages were made use of for the nitrogen balance experiments.

D. Evaluation of protein quality:

A variety of methods based on growth, nitrogen balance, and carcass analysis were used to evaluate the protein quality.

1. Growth studies:

The rate of growth of weanling rats measured under standard conditions provide a reliable measure of the dietary protein value (NRC, 1963).

Fifty male albino rats were grouped into five groups of ten rats each. The diets were weighed, mixed with boiling water to a thin batter consistency and fed ad libitum (Tasker et al. 1960). The left over food was dried in an oven cooled and weighed. The quantity of food consumed daily was noted down. Rats were weighed individually on alternate days throughout the experimental period of twenty eight days. Measurements used for evaluation based on growth were:

a. Weight gain and food intake:

Both weight gain and food intake which reflect the quality of protein given (Munro and Allison, 1964) served as the basis of evaluation of the diets.

b. Protein Efficiency Ratio (PER):

The total intake of protein was calculated for each rat from the total food intake and from the records of weight gain and protein intake, the protein efficiency ratio was calculated using the formula:

$$\text{PER} = \frac{\text{Gain in Weight (g)}}{\text{Total Protein consumed (g)}}$$

(NRC, 1963; Beaton and McHenry, 1964)

When young rats are fed diets varying in protein content, the measure of change in body weight is a fairly good estimate of the change in body protein (Pellette, 1973).

c. Hepatic weight and nitrogen:

The rat liver, a sensitive indicator of protein nutrition (Campbell and Kosterlitz, 1948; and Waine et al. 1953) contains labile proteins and responds to increase in nitrogen intake and to improved nutritive value of dietary proteins (Allison et al. 1962).

The initial hepatic weight and nitrogen were determined by sacrificing a group of weanling rats at the beginning of the experiment. At the termination of the PER study the rats were chloroformed and the livers removed carefully and stored after weighing. The livers were pooled into three groups of equal weight. Pooled livers were homogenised well and the nitrogen content estimated by taking 0.2 g of the liver in triplicates using the micro kjeldahl method (Hawk, 1965; Crooke, 1971). From the initial and final liver nitrogen, the nitrogen retention per gram of liver was calculated for each diet.

d. Hepatic fat:

The hepatic fat content of each of the groups of liver was estimated in triplicates using the method described by Folch et al. (1957).

2. Nitrogen balance studies:

a. Depletion period:

The animals were maintained on a protein free diet (Starch 86% and fat 8% with the addition of vitamin and mineral mixtures) for a period of seven days. The first three days were the adjustment period and the last four days were the collection period (Ambegaokar et al. 1969 and Intengan and Major, 1971).

Urine was collected daily in conical flasks the volume measured and preserved under toluene (Risser, 1946). Faecal samples were collected daily and bulked for each rat at the end of the collection period. To ensure proper collection ferric oxide was used as a marker. The faecal matter was brushed well to remove food particles and hair, weighed, dried and preserved in polythene bags (Mitchell et al. 1936).

Weight of each rat was recorded on the eighth day of the depletion period, and the reduction in weight calculated. The rats were divided into five groups of six each so as to have an equal average weight for each group.

b. Repletion period:

All the depleted rats were fed the stock diet for four days followed by the experimental diets for the next seven days. A record of food intake was maintained. The protein and nitrogen intakes were calculated. The urine and faeces for the last four days were collected and preserved.

The urine and faeces were pooled for each metabolic period and analysed for the nitrogen content in triplicates using the micro kjeldahl method (Hawk et al. 1965). The nitrogen excretion during the

depletion period formed the endogenous and metabolic nitrogen whereas, that of the repletion period represented the nitrogen retention due to the food protein.

The total excretion of endogenous, metabolic urinary and faecal nitrogen by each rat for the four days were calculated which formed the basis of calculation of the Biological value, using the formula:

$$BV = \frac{\text{Nitrogen intake} - (\text{Faecal } N_2 - \text{Endogenous Faecal } N_2) - (\text{Urinary } N_2 - \text{Endogenous urinary } N_2)}{\text{Nitrogen intake} - (\text{Faecal } N_2 - \text{Endogenous faecal Nitrogen})}$$

(NAS/NRC 1963)

3. Methods based on carcass nitrogen analysis:

The Net Protein Utilisation and NDp calories were the indices based on carcass analysis.

Thirty six weanling male albino rats 23 days old were maintained on the stock diet for a period of one week after which they were weighed and divided into six groups. The experimental diets were fed to four groups, the non-protein diet to the fifth group and the skim milk diet to the sixth group for ten days, (Sreenivas et al. 1966; Bailus and Chenoy, 1969).

The groups of carcasses were dried for 48 hours in an oven at 105°C to obtain constant weight. After cooling to room temperature the carcasses were weighed. The heating, cooling and weighing continued till constant weight was obtained. The moisture content was calculated from the difference between the initial and final weights.

The carcasses were then ground, homogenised and the nitrogen content of carcass per gram was estimated in triplicates using macro Kjeldahl method (Hawk et al. 1965).

NPU of each diet was calculated using the formula given by Chalupa and Fisher (1963):

$$\text{NPU} = \frac{\text{BF} - \text{BK} + \text{IK}}{\text{IF}} \times 100$$

where BF and IF denote carcass nitrogen and nitrogen intake of animals fed the test diets respectively, and BK and IK equal carcass nitrogen and nitrogen intake of animals fed the protein free and control diet respectively.

NDp calories per cent was calculated for each diet using the following formula: (NRC, 1963).

$$\begin{aligned} \text{NDp calories per cent} &= \frac{\text{Retained protein (Expressed in cal)}}{\text{Total metabolizable energy in the food consumed}} \times 100 \\ &= \frac{\text{Retained N(g)} \times 6.25 \times 4 \text{ Kcal}}{\text{Total food intake (g)} \times (\text{K cal/g food})} \end{aligned}$$

IV. RESULTS AND DISCUSSION

The results of this investigation on the evaluation of the protein quality of ragi-based diet mixtures on albino rats are presented and discussed under the indices of:

- A. Growth pattern
- B. Hepatic weight, nitrogen and fat
- C. Nitrogen balance
- D. Carcass nitrogen analysis

A. Growth pattern:

Weight gain, food intake and protein intake and Protein Efficiency Ratio (PER) constitute the data gathered under the growth indices and is discussed below.

1. Weight gain:

Mean weight gains of rats fed the ragi-basal diet, the three ragi-based diet mixtures and the skim milk control diet over an experimental period of 28 days is presented in Table IV. The weight gains of individual rats are given in Appendix V.

TABLE IV

MEAN GAIN IN WEIGHT OF RATS FED DIFFERENT DIETS

Diet	Sources of protein	Initial weight (g)	Final weight (g)	Gain in weight (g)	Groups compared	t value
I.	Ragi basal	31.76 ^a ± 5.95	58.96 ± 4.83	27.20 ± 4.75	I VS II I VS III I VS IV I VS V	9.72 ** 11.93 ** 10.16 ** 11.72 **
II.	Ragi basal + Horse gram (11) + Sesame (6) + Ground nut (5)	31.51 ± 5.82	86.75 ± 8.06	55.24 ± 7.24	II VS III II VS IV II VS V	0.30 0.42 2.99 *
III.	Ragi basal + Horse gram (8) + Sesame (6.25) + Ground nut (7)	31.69 ± 3.10	85.97 ± 9.15	54.28 ± 6.16	III VS IV III VS V	0.13 3.39 **
IV.	Ragi basal + Horse gram (8) Sesame (7.75) + Ground nut (7.25)	31.53 ± 2.84	85.44 ± 4.67	53.91 ± 6.51	IV VS V	3.49 **
V.	Skim milk	32.99 ± 4.01	99.58 ± 10.18	66.59 ± 8.88	-	-

** Significant at one per cent level
* Significant at five per cent level
^a Standard deviation

The rats fed skim milk registered the highest gain in weight, 66.59 g. The Mean gain in weight of rats fed the ragi basal diet (Diet I) was the least (27.20 g). Gain in weight of rats on ragi-based diet mixtures II, III and IV were 55.24, 54.28 and 53.91 g respectively. The ragi basal diet, the diet pattern actually consumed by the local people seems to be the least effective in promoting growth. Similar values for growth gain has been reported by Daniel et al (1967) for blends of ragi, Bengal gram, groundnut meal and skim milk. Statistical analysis indicated that the difference in weight gain of rats fed ragi basal diet was significantly lower than that of all the other diets at one per cent level. The difference in weight of rats fed skim milk was significantly higher at five per cent level than that of diet II and at one per cent level when compared with diets III and IV. There was however no significant difference between the weight gains of rats fed the three ragi based diet mixtures.

The growth pattern of the rats fed the five diets is depicted in Figure I. It is evident from the growth curves that the increase in weight registered by rats fed skim milk was much higher than that of rats fed the

SCALE

X - Axis, 2 cms = 1 Week

Y - Axis, 1cm = 10 g.

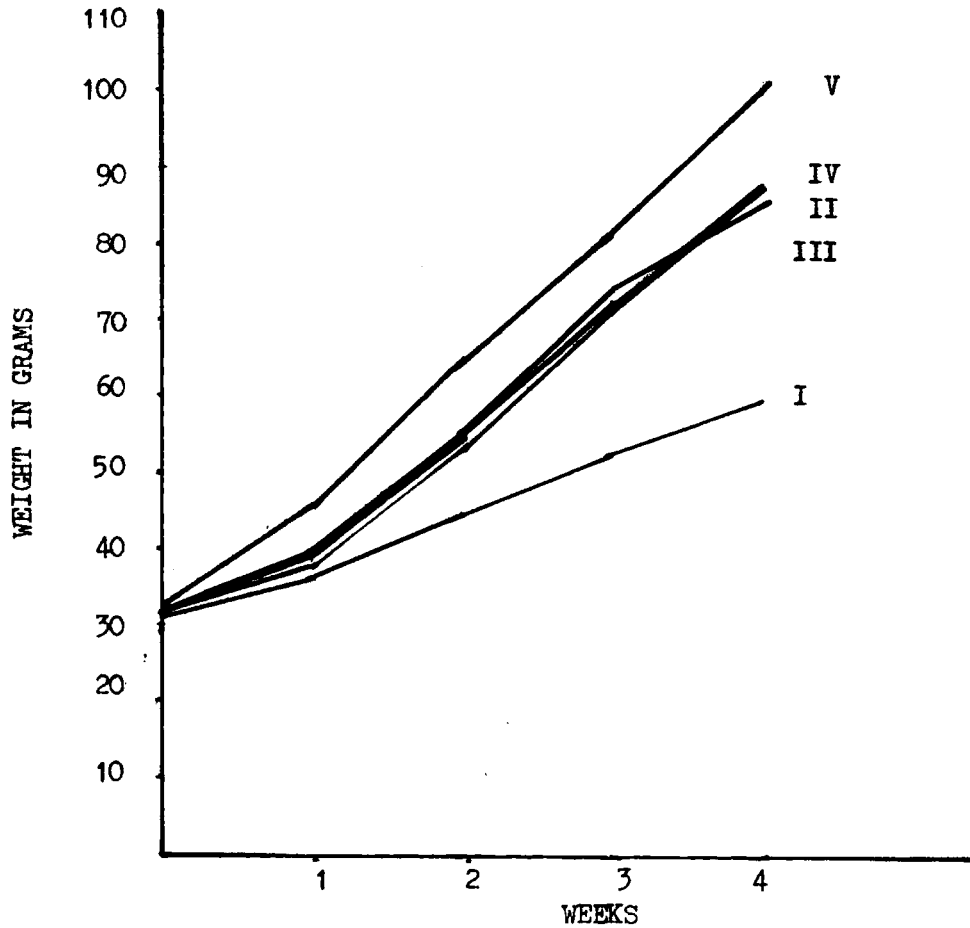


FIGURE I

GROWTH PATTERN OF THE RATS

KEY

- | | | | |
|-----|---|----|---------------------------------|
| I | RAGI BASAL | IV | RAGIBASAL+HORSEGRAM (8) |
| II | RAGIBASAL+HORSEGRAM(11)+
SESAME (5)+GROUNDNUT (5). | | + SESAME (7.5)+GROUNDNUT (7.25) |
| III | RAGIBASAL + HORSEGRAM (8)+
SESAME (6.25)+ GROUNDNUT (7). | V | SKIM MILK |

ragi basal and the three ragi based diet mixtures.

A comparison of the total weights of the animals fed the five diets is also evident from Figures 2, 3, 4 and 5.

2. Food intake and protein intake:

The level of protein in the ragi basal diet (Diet I) was eight per cent but that of the three ragi based diet mixtures and of skim milk diet was maintained constant at ten per cent level and hence the changes in protein intake is directly related to the changes in food intake.

The mean total food and protein intake of rats fed the five different diets are presented in Table V. The total food intakes of individual rats are given in Appendix VI.

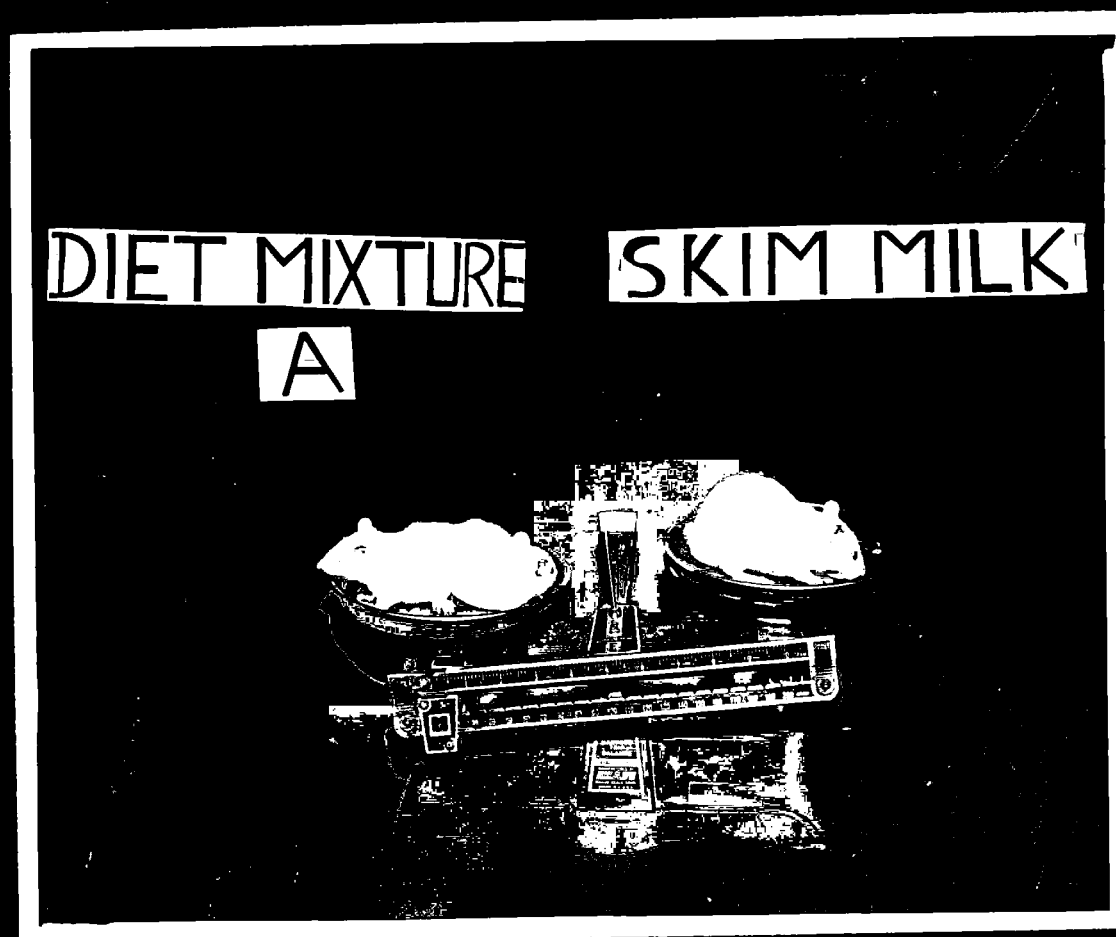


FIGURE 2
WEIGHT GAIN OF RATS FED RAGI BASAL DIET
VERSUS SKIM MILK



FIGURE 3

COMPARISON OF THE WEIGHT GAIN OF RATS FED RAGI BASAL +
HORSE GRAM (11) + SESAME (5) + GROUNDNUT (5) WITH
SKIM MILK



FIGURE 4

WEIGHT GAIN OF RATS FED RAGI BASAL + HORSE GRAM (8) +
SESAME (6.25) + GROUND NUT (7) VERSUS SKIM MILK



FIGURE 5

WEIGHT GAIN OF RATS FED RAGI BASAL + HORSE GRAM (8)
+ SESAME (7.75) + GROUND NUT (7.25) AND SKIM MILK

TABLE V

FOOD AND PROTEIN INTAKE OF THE RATS FED THE FIVE DIETS

Diet	Source of protein	Food intake (g)	Protein intake (g)	Groups compared	't' value
I.	Ragi basal	173.95±19.27	13.70±0.54	I Vs II	4.36**
				I Vs III	11.97**
				I Vs IV	13.37**
				I Vs V	15.97**
II.	Ragibasal + Horsegram (11) + Sesame (5) and groundnut (5)	210.74±15.95	21.24±1.51	II Vs III	0.63
				II Vs IV	0.84
				II Vs V	1.33
III.	Ragibasal + Horse gram (8) + Sesame (525) and groundnut (7)	205.53±13.62	20.76±1.70	III Vs IV	0.15
				III Vs V	0.51
IV.	Ragi basal + Horse- gram (8) + Sesame (7.75) + groundnut (7.25)	203.58±12.65	20.65±1.45	IV Vs V	0.41
V.	Skim milk	203.50±11.62	20.40±1.15	-	-

** Significant at one per cent level

* Significant at five per cent level

The animals fed Diet II record the highest food intake of 210.74 g. The rats fed Diet III, IV and V ranked second, third and fourth in their food intake and rats fed the ragi basal diet (Diet I) had the least mean food intake of 173.95 g.

In tune with the food intake, the highest protein intake was registered by rats fed Diet II namely 21.24g, followed by Diets III, IV and V having the protein intakes of 20.76, 20.65 and 20.40 g respectively. The least intake of protein was obtained for rats fed the ragi basal diet (13.70 g).

The analysis of the significance of difference in protein intake between the different diets indicated that the differences between the ragi basal diet was significant at one per cent level, when compared with the other diets. However the difference between the other diets were not statistically significant.

Evidence in the literature have established a linear relationship between the food intake and the quality of protein (Munro and Allison, 1964 and Bender, 1975). The higher food and protein intakes of rats fed ragi basal diet, might be due to the better quality of protein in these diets.

3. Protein Efficiency Ratio (PER):

The mean gain in weight and protein intake of rats fed different diets and PER of the diets are presented in Table VI. The details regarding the same for all the animals are given in Appendix VII.

TABLE VI

WEIGHT GAIN, PROTEIN INTAKE AND PER OF THE RATS FED THE FIVE DIETS

Diet	Source of protein	Weight gain (g)	Protein intake (g)	PER	Groups compared	't' value
I.	Regi basal	27.20 \pm 4.75	15.70 \pm 0.54	1.99 \pm 0.195	I VS II	6.160 **
					I VS III	5.320 **
					I VS IV	5.960 **
					I VS V	9.480 **
II.	Regi basal + Horse gram (11) + Sesame (5) and ground nut (5)	55.24 \pm 7.24	21.24 \pm 1.51	2.60 \pm 0.205	II VS III	0.017
					II VS IV	0.096
					II VS V	4.920 **
III.	Regi basal + Horse gram (8) + Sesame (6.26) and ground nut (7)	54.28 \pm 6.16	20.76 \pm 1.70	2.61 \pm 0.530	III VS IV	-
					III VS V	3.070 *
IV.	Regi basal + Horse gram (8) + Sesame (7.75) and ground nut (7.25)	53.91 \pm 6.31	20.65 \pm 1.45	2.61 \pm 0.245	IV VS V	3.070 *
V.	Skim milk	66.59 \pm 8.81	20.40 \pm 1.15	3.26 \pm 0.350	-	-

** Significant at one per cent level

* Significant at five per cent level

The highest PER value of 3.26 was obtained for the skim milk diet. The lowest PER value of 1.99 was obtained for the ragi basal diet (Diet I). The PER values of Diets II, III and IV were 2.60, 2.61 and 2.61 respectively.

Statistical analysis for differences in PER among different diets pointed out that the PER value of ragi basal diet (Diet I) was significantly ($P < 0.01$) lower when compared with all other diets. The PER value of skim milk diet (Diet V) was significantly higher at one per cent level when compared with that of the Diet II and at five per cent level as against the Diet III and IV, whereas there was no significant difference between the PER values of the three ragi based diet mixtures.

PER values are proportional to the respective protein intakes and weight gains. Joseph et al. (1972) and Daniel et al. (1967) and Daniel ~~et al.~~ have reported PER values of 2.25 and 2.63 for ragi based blends. Devadas et al. (1973) has reported a PER value of 1.90 for ragi basal and a range of 2.20 to 2.66 for ragi based diet mixtures using low cost locally available foods. The values obtained in this investigation are in line with the observations in the literature and PER values as high as 2.6 has been obtained for ragi based diet mixtures. Chandrasekhar et al. (1975) have reported PER values of 3.26 and 3.81 for proteins like skim milk and corn-soya-milk and a PER value of 1.99 for the weaning vegetable

protein mixture Balahar. The results of this study are in accordance to the earlier observations in the literature.

B. Hepatic weight, nitrogen and fat:

1. Hepatic weight and nitrogen:

The mean hepatic weight, total hepatic nitrogen and nitrogen per gram of the liver sample are recorded in Table VII. The details are given in Appendix VIII.

TABLE VII

MEAN HEPATIC WEIGHT, TOTAL HEPATIC NITROGEN AND NITROGEN/GRAM OF LIVER OF RATS FED DIFFERENT DIETS

Diet	Source of protein	Mean hepatic weight (g)	Total hepatic nitrogen (mg)	Hepatic nitrogen mg/g of liver	Groups compared	't' value for total hepatic nitrogen
I.	Ragi basal	1.30±0.14	41.89±4.60	32.20±2.12	I VS II	5.99*
					I VS III	5.58*
					I VS IV	5.24*
					I VS V	13.45**
II.	Ragi basal + Horse gram (11) + Sesame (5) ground nut (5)	2.15±0.15	66.16±3.94	30.80±1.88	II VS III	2.36
					II VS IV	1.20
					II VS V	8.59*
III.	Ragi basal + Horse gram (8) + Sesame (6.25) + Groundnut (7)	2.47±0.17	82.77±9.13	33.46±2.83	III VS IV	1.20
					III VS V	2.56
IV.	Ragi basal + Horse gram (8) + Sesame (7.75) + Groundnut (7.25)	2.39±0.11	72.97±7.02	30.53±1.40	IV VS V	4.85*
V.	Skim milk	4.44±0.22	100.95±4.16	22.74±0.43		

** Significant at one per cent level

* Significant at five per cent level

Maximum liver weight of 4.44 g was recorded by rats fed skim milk diet, next ranked rats fed Diet III with 2.47 g, followed by rats fed Diet IV (2.39 g), Diet II (2.15 g) and ragi basal diet (1.30 g).

The highest hepatic nitrogen was obtained by rats fed skim milk (100.95 mg). Rats fed Diet III ranked second with a mean hepatic nitrogen content of 82.77 mg, followed by rats fed Diet IV, 72.97 mg and Diet II, 66.16 mg respectively. Rats fed the ragi basal diet had the least hepatic nitrogen content of 41.89 mg. The highest nitrogen per gram of liver was recorded by rats fed Diet mixture III (33.46 mg). Rats fed Diet mixtures II and IV had almost similar values of nitrogen per gram of liver namely, 30.80 and 30.53 mg respectively. Rats fed the ragi basal diet (Diet I) registered a value of 32.20 mg/g liver sample whereas that of rats in skim milk was only 22.74 mg/g liver sample. The lower value obtained for skim milk may be due to the fact that hepatic nitrogen/g liver sample is only a ratio between the total nitrogen deposited and total hepatic weight and both these indices are higher for skim milk diet.

Statistical analysis for differences in total hepatic nitrogen among all the ragi based diets were not significant. However, the differences between each of the ragi based diets and skim milk was significant at one per cent level.

Devadas et al. (1970), and Chandrasekhar et al. (1975, 1976) have reported that the liver weights were proportional to the body weights. The results of this study also indicate the same trend in hepatic weight gains as against the body weight gains. Addis et al. (1940), Henry et al. (1958, 1961) and Kewatra et al. (1970) have observed a linear relationship with hepatic nitrogen and protein quality. The higher the nitrogen retention, better is the protein quality of the foodstuff. It may be that ragi based diet mixture III which had a better total hepatic nitrogen retention as well, when compared with the other ragi diets, has a protein of good quality.

2. Hepatic fat:

The mean hepatic fat and gram of fat per gram of liver are given in Table VIII. The total hepatic fat and the gram of fat per gram of liver for the three groups in all the five diets are given in Appendix VIII.

TABLE VIII

TOTAL HEPATIC FAT AND FAT/GRAM OF LIVER OF RATS FED DIFFERENT DIETS

Diet	Source of Protein	Mean Hepatic weight (g)	Total hepatic fat (g)	Hepatic fat/g of liver sample	Groups compared	't' value
I.	Ragi basal	1.30±0.14	0.07±0.02	0.06±0.02	I VS II I VS III I VS IV I VS V	0.01 0.60 0.29 1.17
II.	Ragi Basal + Horse gram (11) + Sesame (5) + Ground nut (5)	2.15±0.15	0.11±0.02	0.05±0.01	II VS III II VS IV II VS V	0.59 1.41 1.28
III.	Ragi Basal + Horse gram (8) + Sesame (6.25) + Ground nut (7)	2.47±0.17	0.12±0.01	0.05±0.01	III VS IV III VS V	1.15 1.39
IV.	Ragi Basal + Horse gram (8) + Sesame (7.75) + Ground nut (7.25)	2.38±0.11	0.14±0.02	0.06±0.01	IV VS V	1.14
V.	Skin milk	4.44±0.22	0.46±0.25	0.10±0.06		-

The highest hepatic fat was recorded by rats fed skim milk (0.46 g). The least hepatic fat was recorded by rats fed the ragi basal diet (Diet I 0.07 g). The total hepatic fat of rats fed the three ragi based diet mixtures (Diets II, III and IV) were 0.11, 0.12 and 0.14 respectively. The same trend was observed when grams of fat per gram of liver was considered.

Statistical analysis for differences in hepatic fat per gram liver indicated that there was no significant difference between the fat deposition in liver of rats fed different diets.

The values obtained are in good agreement with those of the values reported by Devadas et al. (1973) for ragi based diets. Marfatia et al. (1960) report that on feeding the protein of poor quality the weight gain obtained is probably mainly due to fat. Phasalkar (1960), states that quality as well as the quantity of proteins play an important role in the prevention of dietary liver damage. The results obtained for ragi basal diet (Diet I) is in good agreement with the findings in the literature and it may be that the fatty infiltration of the liver has occurred. In spite of the fact that the protein level is only eight per cent, the deposition of fat has been equal to that of other ragi based diets.

C. Nitrogen Balance:

1. Nitrogen retention:

The mean total intake, excretion, absorption and retention of nitrogen by the rats fed the five different diets are presented in Table IX. The details pertaining to individual rats are given in Appendix IX.

TABLE IX

MEAN INTAKE, EXCRETION, ABSORPTION, RETENTION AND RETENTION PERCENTAGE OF NITROGEN FOR THE RATS FED DIFFERENT DIETS

Diet	Source of Protein	Nitrogen intake (mg)	Nitrogen Excreted (mg)	Nitrogen Absorbed (mg)	Nitrogen Retained (mg)	Nitrogen Retention percent	't' value
I.	Ragi basal	783.0±	188.9±	664±	594±	75.6±	I VS II 1.39
		87.97	51.21	81.83	87.82	4.12	I VS III 0.75
II.	Ragi basal + Horse gram (11) + Sesame (5) + Ground nut (5)	813.0±	159.5±	706±	653.5±	80.2±	II VS III 0.02
		86.82	47.64	92.83	99.97	6.13	II VS IV 0.03
III.	Ragi basal + Horse gram (8) + Sesame (6.25)+ground nut (7)	761.0±	155.7±	656±	604.8±	79.2±	III VS IV 0.17
		31.21	65.14	77.97	93.12	9.88	III VS V 5.69**
IV.	Ragi basal + Horse gram (8) + Sesame (7.25) + Ground nut (7.25)	778.0±	174.2±	659.4±	625.5±	80.1±	IV VS V 6.69**
		41.81	60.35	32.76	82.89	6.42	
V.	Skim milk	824.0±	335.74±	550.02±	488.26±	40.4±	
		58.37	110.10	121.91	92.28	11.6	

** Significant at one per cent level

* Significant at five per cent level

When the nitrogen retention percentages of different diets were compared, ragi based diet mixtures had a retention of 80.2, 79.2 and 80.1 per cent respectively for Diets II, III and IV and 75.6 per cent for ragi basal diet. Skim milk seems to have a lower value in retention and this may be due to the proportionate values obtained for excretion. The values reported are however similar to those reported by Chandrasekhar et al. (1975). The fact that inspite of its higher retention efficiency, the ragi based diets did not promote growth comparable to that obtained with skim milk indicates that the protein quality may not be as good as skim milk.

2. Biological Value and Digestibility Coefficient:

The Biological Value and Digestibility Coefficient calculated from the nitrogen balance data are presented in Table X and details are given in Appendix X.

TABLE I

BIOLOGICAL VALUE AND DIGESTIBILITY COEFFICIENT OF THE FIVE DIETS

Diet	Source of protein	Biological Value	't' test	Digestibility Coefficient	't' test
I.	Ragi basal	89.00 \pm 2.28	I VS II	84.70 \pm 2.30	I VS II
			I VS III		I VS III
			I VS IV		I VS IV
			I VS V		I VS V
II.	Ragi basal + Horse gram (11) + Sesame (6) + ground nut (5)	92.30 \pm 4.18	II VS III	86.80 \pm 4.31	II VS III
			II VS IV		II VS IV
			II VS V		II VS V
III.	Ragi basal + Horse gram (8) + Sesame (6.25) + ground nut (7)	91.70 \pm 3.33	III VS IV	86.20 \pm 6.31	III VS IV
			III VS V		III VS V
IV.	Ragi basal + Horse gram (8) + Sesame (7.75) + Ground nut (7.25)	91.70 \pm 1.38	IV VS V	84.70 \pm 2.24	IV VS V
V.	Skim milk	88.71 \pm 7.84		66.75 \pm 5.26	

** Significant at one per cent level

* Significant at five per cent level

The highest Biological Value of 92.30 was obtained for ragi based diet mixture II and that of skim milk diet was the lowest 88.71. Diets III and IV (91.70) and Diet I (89.00) ranked second and third respectively in their Biological Value. Statistically the difference between ragi based diets when compared with the skim milk was significant at one per cent level.

Diet II had registered the highest Digestibility Coefficient of 86.80 followed by 86.20 for Diet III, 84.70 for Diets IV and I and 66.75 for Skim milk. Statistical appraisal indicated that the differences between the Digestibility Coefficient among ragi based diets (Diet I to IV) were not significant but when compared with the skim milk diet all the four ragi based diets was significantly different at one per cent level.

Block and Mitchell (1946) brought forward the evidence that the Biological Value of a protein depended to a large extent on its essential amino acid composition. Phansalkar (1960) reports that the BV of cereal protein varied between 60 to 89 per cent and those of legumes between 45 and 74 per cent. Hardings et al. (1966), Devadas et al. (1975) have reported that a combination of legumes, whole grains, nuts and vegetables provided

satisfactory combination of amino acids and hence better Biological Value. The results obtained for BV in the present investigation for ragi based diets are in line with those of the values for ragi based diet mixtures reported by Devadas et al. (1973).

Akerson and Shahuran (1965) claimed that the nutritive value was not significantly affected by the digestibility and this explains the lower BV and DC values obtained to skim milk. Beaton and McHenry (1964) and Bender (1965) state that the variability in digestibility of proteins is not a major determinant of the nutritive value of proteins and hence the absence of correlation between the BV and DC and other indices for the various diets is well answered.

D. Carcass nitrogen analysis:

1. Net Protein Utilisation (NPU):

The NPU values obtained through carcass nitrogen analysis are given in Table XI. The details are presented in Appendix XI.

TABLE XI

NET PROTEIN UTILISATION AND NET DIETARY PROTEIN CALORIES OF THE DIFFERENT DIETS

Diet	Source of protein	Mean body nitrogen (g)	Nitrogen consumed (g)	Net protein utilisation	Net Dietary protein calories percent	Groups compared	Net protein utilisation	Net Dietary protein calories percent
I.	Ragi basal	6.66±	5.58±	64±	7.20±	I VS II	14.70**	1.06
		0.42	1.57	1.45	0.15	I VS III	2.11	1.15
II.	Ragi basal + Horse gram (11) + Sesame (5) + ground nut (5)	7.23±	6.60±	74±	8.70±	II VS III	3.33*	0.13
		1.38	0.44	0.5	0.28	II VS IV	-	3.07*
						II VS V	3.54*	4.64**
III.	Ragi basal + Horse gram (8) + Sesame (6.25) + ground nut (7)	7.11±	6.23±	68±	8.90±	III VS IV	1.61	1.77
		0.84	0.37	4.0	1.04	III VS V	4.89**	2.12
IV.	Ragi basal + Horse gram (8) + Sesame (7.75) + ground nut (7.25)	6.97±	7.90±	74±	9.46±	IV VS V	1.84	0.09
		0.98	0.50	7.28	0.89			
V.	Skim milk	7.94±	6.86±	81±	10.00±			
		0.47	1.40	4.4	0.56			

** Significant at one per cent level

* Significant at five per cent level

The mean total body nitrogen of rats varied from 6.66 mg. to 7.94 g. When the NPU obtained for different diets were compared, skim milk was found to have the highest NPU of 81 followed by 74 for Diets II and IV, 68 for Diet III and 64 for Diet I.

Statistical analysis indicated that the differences between Diet I (ragi basal) and Diet II and V; Diet III and Diet V were significant at one per cent level, whereas that of Diet I and IV, and Diet II and V were significant at five per cent level and that between Diets I and III, II and IV, III and IV and IV and V were not significant.

This observation is in agreement with the previous observations which proved the protein quality of different diets to be in the following order skim milk, ragi based diet mixtures and ragi basal diet. Among the ragi based diet mixtures, although there is no significant difference in the different indices, Diet II seems to have a higher value for most of the indices.

In general, Carcass nitrogen is influenced by the dietary protein (Marshall and Hildebrand, 1963) and the PER values are highly correlated with NPU values (Kon and Kon, 1956; Bender, 1956, 1975). Wohl and Goodhart (1970) state that increments in nitrogenous tissue in the body can be related directly to qualitative amino-acid difference of the test nitrogenous moiety of the

diets. Present observation is in accordance with this and brings out the differences in the quality of different diets studied. The NPU values reported by Devadas et al. (1973), Chandrasekhar et al. (1975) for diets based on ragi and for those of protein mixture like CSM, Balahar and simple proteins like skim milk.

2. NDp Calories per cent(NDp cal%):

The NDp cal% calculated from the protein retained, and total metabolisable calorie intake is an index of the quality of protein in mixed diet. The NDp cal% thus calculated for the five diets along with the statistical analysis is presented in Table XI. The details are given in Appendix XI.

Skim milk was found to have the highest NDp cal% (10.0) and ragi basal diet (Diet I) the least (7.2). The ragi based diet mixtures, Diet II, III and IV had NDp cal% values of 8.70, 8.90 and 9.46 respectively. Statistically, the differences between the NDp cal% values between Diets I and IV, I and V and II and V were significant at one per cent level and that between II and IV at five per cent level. The differences between all other comparisons were not significant. These results are in tune with the results obtained for other indices in that, skim milk had a higher value and that of ragi basal was the least. The difference between the ragi based diet mixtures were not appreciable.

Thus, judged from all parameters skim milk was found to be superior in its protein quality when compared with the ragi based diets. It promoted higher weight gains, better nitrogen retention in the liver and carcass, promoted nitrogen balance and registered higher PER, NPU and NDp calories per cent. Among the ragi diets, ragi basal diet, the diet customarily consumed by the community was the least efficient in all aspects, both in growth and nitrogen retention. Addition of low cost locally available foods to this ragi basal diet resulted in a marked improvement of the dietary protein quality although not equal to that of skim milk. When all the parameters are taken into consideration, there were no appreciable differences between the three ragi based diet mixtures. However Diet II seem to be slightly better among the three ragi based diet mixtures. Since, there does not seem to be much improvement in protein quality inspite of working out several permutations and combinations of the vegetable protein mixtures, it may be worthwhile to further enhance the value of these diets by inclusion of small quantities of animal protein sources like skim milk. Possibilities of enhancing the quality further also could be approached through the usage of new oil seeds like Sunflower meal or through the usage of proteins like soy proteins. Research along these line would further strengthen the information on ragi based diets and also open up new arenas of feeding the malnourished population groups.

V. SUMMARY AND CONCLUSION

The main objective of the present investigation was to evaluate the protein quality of ragi based diet mixtures using albino rats. The ragi based diets consumed by the community in Coimbatore district constituted the basal dietary pattern around which the other ragi based diet mixtures were formulated by incorporating low cost locally available foods. The ragi basal diet had a protein content of 8.04 per cent. Several permutations and combinations by incorporating the low cost locally available foods like horsegram, sesame, groundnut raising the protein level to 10 per cent and calculation of their amino acid pattern and chemical score resulted in the selection of three ragi-based diet mixtures. The three ragi based diet mixtures consisted of ragi basal plus horsegram, sesame and groundnut in the ratios of 11:5:5 (Diet II); 8:6:25:7 (Diet III) and 8:7.75: 7.25 (Diet IV) respectively. A fifth Diet (Diet V) with skim milk at 10 per cent protein level served as the control. The five diets thus formulated were evaluated on groups of:

1. Weanling male albino rats over a period of 28 days using the criteria of weight gain, food and protein intake, PER, hepatic weight, hepatic nitrogen and hepatic fat.

2. Adult male rats for a period of 14 days using the parameter of nitrogen balance to include nitrogen retention per cent, Biological Value and Digestibility Coefficient; and
3. Weanling male rats over a period of ten days, using the indices of Net Protein Utilization and NDp calories per cent.

The results revealed that:

1. The mean body weight increases were 66.59, 55.24, 54.28, 53.91 and 27.20 g, respectively for Diet V (skim milk), Diets II, III and IV (ragi based diet mixtures) and Diet I (ragi basal diet) fed rats. The increase in weight was significant at one per cent level for all diets except between the three ragi based diet mixtures.
2. The total food intake ranged from 173.95g (ragi basal) to 210.74 g (Diet II). Subsequently the protein intake ranged from 13.70 g (Diet I) to 20.76 g (Diet II). The ragi basal diet group had a significantly lower protein intake, ($P < 0.01$) when compared with the other groups.
3. The highest PER was obtained for skim milk (3.26) and the lowest for ragi basal (1.99). The PER values obtained for the three ragi based diet mixtures were 2.60, 2.61 and 2.61 for Diets II, III and IV respectively. The PER values between the skim milk diet and all other diets were statistically significant ($P < 0.01$). The PER values of the ragi based diet mixtures were significantly higher ($P < 0.01$) when compared with ragi basal diet. However, there were no significant difference between the PER values of three ragi based diet mixtures.

4. Significantly higher hepatic weight, total hepatic nitrogen and hepatic fat were registered by animals fed skim milk diet. The total hepatic nitrogen obtained for ragi basal was significantly lower than that of the three ragi based diet mixtures at five per cent level and that of the skim milk diet at one per cent level. Except between Diets III and IV, which was significant at five per cent level, there were no significant difference between the hepatic nitrogen content of the three ragi based diets. There were no significant difference, in the hepatic fat deposition for all the diets.
5. The per cent of nitrogen retention, ranged from 40.4 to 80.2 per cent for the five different diets. The Biological values were 89, 92, 92, 92, and 89 respectively for the five diets and the digestibility Coefficient were 85, 87, 86, 85 and 67 respectively. There were statistically significant difference at one per cent level when the four ragi diets were compared with skim milk diet, for both Biological Value and Digestibility Coefficient. However these values were not significant amongs the ragi based diets.
6. The values obtained for NPU were 64, 74, 68, 74 and 81 respectively for the five diets. Statistically the NPU values between Diets I and II, I and IV and III and V were significant at one per cent level and those between Diets I and IV, II and III and II and V were significant at five per cent level.

7. The NDp calories per cent values for the five diets were 7.2, 8.7, 8.9, 9.5 and 10.0 respectively. Statistical analysis indicated that NDp calories per cent value between Diets I and IV, I and V and II and V were significant at one per cent level and that between II and IV was significant at five per cent level. The others were not significant.

The results of this investigation indicate that when ragi based diets are considered separately, the three ragi based diet mixtures had greater potential over that of the customarily consumed ragi diets of the community, as evaluated through the parameters of growth, nitrogen retention, Net Protein Utilisation and NDp calories %. Skim milk however was more effective. Among the ragi based diet mixtures Diet II seemed to be slightly better, as judged through all the parameters studied, although not on par with the animal protein skim milk. The possibility of enhancing further the protein quality of the ragi based diet mixture with vegetable proteins of higher protein content and better amino acid make up (e.g.) soyproteins or with animal proteins like skim milk is speculated and warrants further investigation. The results of this study however are in line with those of Devadas et al. (1973) and indicates clearly the need and points out the possible measures to upgrade the common ragi based dietaries of the community.

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A P P E N D I C E S

APPENDIX I

COMPOSITION AND PROTEIN CONTENT OF THE DIETS (g/100 g OF DIET)

Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Ragi	38.34	36.34	36.34	38.34	38.59	38.59	35.34	35.34	36.84	36.84	38.09	37.84
Sweet potato	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Morsegram	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Sesame	7.00	8.00	7.50	6.50	6.25	7.00	8.50	8.00	7.75	7.25	7.75	7.75
Apuranthus	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Groundnut	6.50	7.50	8.00	7.00	7.00	6.25	8.00	8.50	7.25	7.75	6.00	6.25
Other ingredients	31.16	31.16	31.16	31.16	31.16	31.16	31.16	31.16	31.16	31.16	31.16	31.16
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Protein	9.81	10.12	10.02	9.95	9.85	9.78	10.27	10.31	10.05	10.10	9.81	9.86

APPENDIX II

AMINO ACID PATTERN OF THE DIETS

Mixture Number	Amount	Total nitrogen	Arginine	Histidine	Lysine	Tryptophan	Phenylalanine + tyrosine	Cystine + Methionine	Threonine	Leucine	Isoleucine	Valine	Total
A.	100	1.178	0.3931	0.1467	0.2897	0.0830	0.5337	0.4317	0.1921	0.5401	0.3368	0.4386	3.3655
B.	100	1.590	0.8047	0.2971	0.5514	0.1078	0.7981	0.4392	0.3243	0.7962	0.4962	0.5475	5.1625
1.	100	1.663	0.6465	0.2128	0.2953	0.1199	0.5707	0.3482	0.2915	0.5721	0.4148	1.1531	4.6259
2.	100	1.665	0.7131	0.0201	0.3503	0.1110	0.5897	0.3492	0.2935	0.5901	0.4258	0.4881	3.8109
3.	100	1.668	0.7095	0.2928	0.3523	0.1190	0.5797	0.3532	0.3015	0.5851	0.4258	0.481	4.1069
4.	100	1.663	0.6565	0.1998	0.2963	0.1199	0.5707	0.3482	0.2915	0.5901	0.4258	0.4881	3.8109
5.	100	1.662	0.6695	0.2018	0.3883	0.1179	0.5697	0.3472	0.2935	0.6061	0.3728	0.1163	3.6810
6.	100	1.661	0.7115	0.2038	0.3853	0.1169	0.5597	0.3472	0.2945	0.6241	0.4078	0.4851	4.1339
7.	100	1.669	0.7125	0.2048	0.3883	0.1069	0.6067	0.3582	0.3065	0.5981	0.4208	0.4951	4.2009
8.	100	1.668	0.7205	0.2068	0.3923	0.1059	0.6057	0.3452	0.2455	0.4661	0.4138	0.4903	3.8921
9.	100	1.665	0.5304	0.1988	0.3773	0.1029	0.4564	0.3392	0.2895	0.5701	0.4098	0.4891	3.7635
10.	100	1.667	0.6884	0.2018	0.3843	0.2649	0.5817	0.3480	0.2905	0.5791	0.4138	0.4951	4.2376
11.	100	1.663	0.6485	0.1958	0.3753	0.1049	0.4387	0.332	0.2915	0.5681	0.4103	0.4761	3.8424
12.	100	1.626	0.6355	0.1978	0.3723	0.1049	0.5637	0.3412	0.2885	0.5701	0.4118	0.2743	3.7601

APPENDIX III
CHEMICAL SCORE OF DIETS

Mixture Number	Lysine %	Tryptophan %	Methionine Cystine %	Threonine %
A	82	94	100	68
B	100	87	100	81
1	51	84	115	63
2	80	94	85	78
3.	69	88	80	74
4	51	82	69	65
5	85	105	87	81
6	75	91	78	72
7	75	76	79	74
8	73	104	76	69
9	81	89	85	80
10	73	104	76	69
11	79	89	80	77
12	80	90	84	78

APPENDIX IV

COMPOSITION OF VITAMIN AND MINERAL MIXTURE

Vitamin A	1000 I.U.
Vitamin D	100 I.U.
Vitamin K	0.5 mg.
Thiamine	0.5 mg.
Riboflavin	1.0 mg.
Pyridoxine	0.4 mg.
Pantothenic acid	4.0 mg.
Niacin	4.0 mg.
Choline	200.0 mg.
Inositol	25.0 mg.
Para Amino benzoic acid	10.0 mg.
Vitamin B ₁₂	2.0 mg.
Biotin	0.02 mg.
Folic Acid	0.20 mg.
Starch	754.38 mg.

COMPOSITION OF MINERAL MIXTURE (g/kg)

Sodium Chloride	139.3 g
Potassium di hydrogen orthophosphate	389.0 g
Calcium Carbonate	381.4 g
Magnesium Sulphate	57.3 g
Ferrous Sulphate	27.0 g
Manganese Sulphate	4.01 g
Potassium Iodide	0.79 g
Zinc Sulphate	0.548 g
Copper Sulphate	0.477 g
Cobalt Chloride	0.023 g

WEIGHT GAIN OF RATS FED DIFFERENT DIETS

Diet	1	2	3	4	5	6	7	8	9	10
Regl Basal	58.0	34.5	33.1	32.5	32.2	31.3	31.00	28.9	28.5	27.6
Final weight (g)	70.0	60.0	65.9	65.5	62.0	63.6	49.6	49.6	53.5	52.5
Gain in weight (g)	32.0	25.5	30.8	33.0	29.8	31.7	18.6	20.7	25.0	24.9
Regl Basal	39.0	34.5	33.5	32.3	32.2	29.6	29.7	29.2	28.5	27.6
Initial weight (g)	95.0	102.2	83.0	91.0	88.5	86.6	74.5	90.5	82.0	74.2
Final weight (g)	57.0	67.7	49.5	58.7	56.3	57.0	44.8	61.3	53.5	46.6
Gain in weight (g)										
Horse gram (11), Sesame (5) and ground nut (5)	57.6	34.9	33.8	32.3	32.0	30.8	30.5	29.0	27.8	27.7
Regl Basal	104.2	86.4	86.0	94.6	83.4	79.8	90.0	81.2	80.1	74.0
Initial weight (g)	66.6	51.5	52.2	62.3	51.4	49.0	59.5	62.2	52.3	46.3
Final weight (g)										
Gain in weight (g)										
Horse gram (8)	36.1	35.6	34.0	32.3	31.5	30.8	30.7	29.5	27.7	27.1
Regl Basal	99.1	94.6	94.0	80.0	85.3	79.4	76.0	79.6	74.6	91.8
Initial weight (g)	63.0	59.0	60.0	47.7	53.8	48.6	45.3	50.1	46.9	64.7
Final weight (g)										
Gain in weight (g)										
Horse gram (8)	36.4	35.1	31.3	42.4	32.2	32.8	28.6	27.5	31.7	31.9
Regl Basal	97.9	101.3	102.9	109.4	83.3	111.8	91.1	82.8	111.5	105.7
Initial weight (g)	61.5	66.2	71.6	67.0	51.1	75.0	62.5	55.4	79.8	71.8
Final weight (g)										
Gain in weight (g)										
Sesame (7.75) and ground nut (7.25)										
Skim milk										

APPENDIX VI

FOOD INTAKE AND PROTEIN INTAKES OF THE RATS FED THE DIFFERENT DIETS

Diet	Rat Number									
	1	2	3	4	5	6	7	8	9	10
Regi Basal	187.0	182.4	179.7	205.8	180.3	187.0	133.8	158.3	155.2	170.0
Protein intake (g)	15.04	14.67	14.53	16.55	14.50	10.76	10.76	12.73	12.48	13.67
Regi Basal	263.7	250.6	197.7	220.8	206.3	203.7	209.7	214.7	210.5	176.7
+ Horse										
gram (11)										
Sesame (5)										
and Ground										
nut (5)										
Regi Basal	229.7	213.7	227.4	202.3	198.9	207.5	204.2	196.8	184.3	187.6
+ Horse										
gram (8)										
Sesame (6.25)										
and Ground										
nut (7)										
Regi Basal	229.9	206.9	196.0	204.1	201.9	196.5	204.3	204.0	176.6	214.8
+ Horse										
gram (8)										
Sesame (7.75)										
and ground										
nut (7.25)										
Skim Milk	195.7	210.1	209.8	219.1	206.7	211.7	209.1	181.5	212.3	198.9
Protein intake	19.57	21.01	20.98	21.91	18.67	21.17	20.91	18.15	21.23	19.89

APPENDIX VII

WEIGHT GAIN, PROTEIN INTAKE AND PER OF THE RATS FED THE DIFFERENT DIETS

Diet	Rat Number									
	1	2	3	4	5	6	7	8	9	10
Regi Basal	32.0	25.5	50.8	33.0	29.8	31.7	18.6	20.7	25.0	24.9
Weight gain (g)	15.04	14.67	14.53	16.55	14.50	10.76	12.76	12.73	12.48	15.67
Protein intake (g)	2.1	1.7	2.2	2.0	2.1	2.1	1.7	1.6	2.0	1.9
PER	57.0	67.7	49.5	58.7	56.3	57.0	44.8	61.3	53.5	46.6
Regi Basal + Horse gram (11) sesame (5) and ground nut (5)	23.6	23.1	19.97	22.30	20.84	20.58	21.18	21.69	21.26	17.85
Weight gain (g)	2.4	2.1	2.3	2.3	2.4	2.3	2.1	2.8	2.5	2.6
Protein intake (g)	PER	66.6	51.5	52.2	62.3	51.4	49.0	59.5	62.2	52.3
Regi Basal + Horse gram (8) Sesame (6.25) Ground nut (7)	23.43	21.80	23.2	20.63	20.29	21.17	20.83	19.07	18.80	19.14
Weight gain (g)	2.8	2.4	2.3	3.0	2.5	2.5	2.8	3.2	2.7	2.4
Protein intake (g)	PER	63.0	59.0	60.0	47.7	53.8	48.6	45.3	50.1	46.9
Regi Basal + Horse gram (8) Sesame (7.75) and ground nut (7.25)	23.45	21.31	19.99	20.82	20.59	19.9	20.84	20.81	18.01	21.60
Weight gain (g)	2.7	2.7	2.8	3.0	2.3	2.6	2.4	2.1	2.4	2.5
Protein intake (g)	PER	60.9	77.9	71.1	79.5	77.2	77.0	58.0	69.5	71.8
Skim milk	23.29	26.92	26.4	26.4	24.65	25.36	22.27	23.62	21.91	22.78
Weight gain (g)	2.6	2.9	2.9	3.0	3.1	3.1	2.6	2.9	3.3	3.2
Protein intake (g)	PER									

HEPATIC WEIGHT, NITROGEN AND FAT CONTENT OF RATS FED THE FIVE DIETS

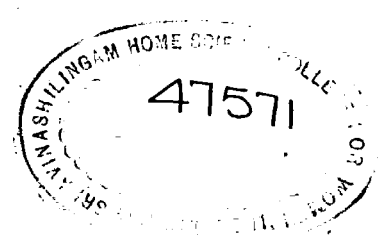
Diet	Source of Protein	Sample Number	Total hepatic weight per group (g)	Total hepatic nitrogen (mg.)	Nitrogen per gram (mg)	Total Hepatic Fat (g)	Fat per gram (g)
I.	Ragi Basal	A	8.3506	45.80	29.60	.09809	0.0634
		B	7.7529	43.51	32.2	.08730	0.0648
		C	8.9742	35.03	34.8	.03151	0.0313
II.	Ragi basal + Horse gram (11) + Sesame (5) + groundnut (5)	A	11.3424	72.54	29.2	.13490	0.0543
		B	11.7914	63.42	32.0	.09831	0.0496
		C	12.8549	62.12	31.4	.10659	0.0539
III.	Ragi basal + Horse gram (8) + Sesame (6.25) and ground nut (7)	A	11.5098	79.39	30.8	.1181	0.0464
		B	11.5739	93.78	34.8	.1299	0.0482
		C	13.4967	75.95	34.8	.1084	0.0497
IV	Ragi basal + Horse gram (8) + Sesame (7.75) + ground nut (7.25)	A	11.1613	80.61	31.0	.1633	0.0628
		B	9.6559	75.23	30.8	.1443	0.0591
		C	12.8549	63.71	29.8	.1118	0.0523
V.	Skim milk	A	13.6926	103.5	22.68	.1220	0.0268
		B	13.6070	94.1	22.40	.5654	0.1346
		C	18.2450	102.1	22.40	.7042	0.1544

APPENDIX IX

INDIVIDUAL EXCRETION OF URINE AND FAECES DURING DEPLETION AND REPLETION PERIOD

 Ragi Basal + Horse gram (11) Ragi Basal + Horse gram (8) +
 + Sesame (5) + Ground nut (5) Sesame (6.25) and ground nut (7)

Rat No.	Ragi Basal		Ragi Basal + Horse gram (11) + Sesame (5) + Ground nut (5)		Ragi Basal + Horse gram (8) + Sesame (6.25) and ground nut (7)							
	Depletion	Repletion	Depletion	Repletion	Depletion	Repletion						
	Wt. of faeces Urine	Wt. of faeces	Vol. of urine	Wt. of faeces	Vol. of urine	Wt. of faeces	Vol. of urine					
1.	3.6	8.1	3.5	10	6.2	12.3	4.4	13.4	4.3	13.9	3.4	12.4
2.	5.2	9.9	3.0	12.7	3.4	12.1	3.0	10.3	3.7	15.4	4.5	11.9
3.	4.0	12.2	5.2	10.2	3.5	12.7	3.5	12.2	3.5	15.0	4.3	14.7
4.	3.4	18.3	4.2	14.2	4.5	15.1	4.0	9.0	4.9	9.9	4.2	10.9
5.	5.3	18.9	4.7	10.1	5.4	12.2	3.7	15.1	3.7	16.2	5.3	9.9
6.	5.2	15.7	4.9	15.0	4.7	16.0	5.0	8.1	4.0	14.7	4.0	8.9



Rat Number	Ragi basal + Horse gram (8) + Sesame (7.75) + Ground nut (7.25)				Skim milk			
	Depletion		Repletion		Depletion		Repletion	
	Wt. of faeces	Vol. of urine	Wt. of faeces	Vol. of urine	Wt. of faeces	Vol. of urine	Wt. of faeces	Vol. of urine
1.	4.2	8.9	3.7	9.8	2.48	11.2	5.65	11.9
2.	4.2	15.5	5.4	8.9	2.64	30.9	4.45	13.6
3.	4.4	9.9	6.2	9.9	1.74	11.5	5.23	8.5
4.	3.0	16.4	4.4	14.0	2.47	48.1	5.39	17.1
5.	4.4	13.3	4.8	8.9	2.01	20.0	5.17	8.2
6.	4.8	12.7	3.1	12.3	2.52	27.0	5.57	18.0

APPENDIX I

EXCRETION OF NITROGEN BY THE INDIVIDUAL RATS

Rat No.	Ragi basal						Ragi basal + Horse gram (11) + Sesame (5) + Ground nut (5)					
	Nitrogen (mg)			Nitrogen (mg)			Nitrogen (mg)			Nitrogen (mg)		
	Endogenous	Metabolic	Urinary	Faecal	Endogenous	Metabolic	Urinary	Faecal	Endogenous	Metabolic	Urinary	Faecal
1.	21.8	69.75	104.1	187.6	22.6	91.8	104.1	240.5				
2.	22.4	98.0	90.8	215.5	25.4	124.0	90.8	196.3				
3.	31.1	101.5	85.0	189.6	25.4	91.9	85.0	187.4				
4.	27.6	76.5	88.9	230.2	31.7	98.0	88.7	288.3				
5.	22.6	71.8	118.5	199.8	25.4	110.25	118.5	274.3				
6.	25.4	97.0	93.0	208.3	35.2	122.20	93.0	263.5				

APPENDIX I

PERCENTAGE NITROGEN RETENTION OF DIFFERENT DIETS PER RAT

Rat No.	Ragi basal		Ragi basal + Horse gram (11) + Sesame (5) + ground nut (7)		Ragi basal + Horse gram (8) + Sesame (6.25) + ground nut (7)	
	Nitrogen intake (mg)	% Retention	Nitrogen intake (mg)	% Retention	Nitrogen intake (mg)	% Retention
1.	838.0	638.7	764.0	683.6	806.0	699.6
2.	838.0	654.6	960.0	831.8	707.0	429.9
3.	692.0	550.0	723.0	590.4	810.0	629.9
4.	857.0	642.9	763.0	555.1	746.0	670.3
5.	636.0	416.9	905.0	708.7	782.0	660.7
6.	838.0	662.3	758.0	551.5	712.0	538.4

APPENDIX X

Ret. No.	Ragi basal + Horse gram (8) Sesame (7.75) and ground nut (7.25)				Sida Milk		
	Nitrogen intake (mg)	Nitrogen retained (mg)	% Retention	Nitrogen intake (mg)	Nitrogen retention (mg)	% Retention	
1.	763.0	598.1	78.4	859.2	289.6	33.7	
2.	749.0	586.0	78.2	776.0	247.5	31.9	
3.	816.0	638.4	78.2	731.2	233.5	31.9	
4.	843.0	790.9	93.8	840.0	551.0	65.7	
5.	765.0	617.6	80.7	824.0	319.9	38.8	
6.	733.0	520.8	71.1	913.6	266.3	40.1	

DIGESTIBILITY COEFFICIENT OF DIFFERENT DIETS PER RAT

Rat No.	Ragi basal		Ragi basal + Horse gram (11) + Sesame (5) + ground nut (5)		Ragi basal + Horse gram (8) + Sesame (6.25) + ground nut (7)				
	Nitrogen intake (mg)	Nitrogen absorbed (mg)	D. C.	Nitrogen intake (mg)	Nitrogen absorbed (mg)	D. C.	Nitrogen intake (mg)	Nitrogen absorbed (mg)	D. C.
1.	838.0	721.0	86.0	764.0	715.5	93.7	806.0	744.6	92.4
2.	838.0	723.0	86.5	960.0	887.7	92.5	707.0	518.0	73.3
3.	692.0	603.9	87.3	728.0	632.5	86.9	810.0	686.0	84.7
4.	857.0	699.7	81.6	763.0	642.7	84.2	746.0	699.6	93.8
5.	636.0	508.0	79.9	905.0	740.9	81.9	782.0	702.9	89.9
6.	838.0	729.0	87.0	758.0	616.7	81.4	712.0	589.2	82.8

APPENDIX X

DIGESTIBILITY COEFFICIENT OF DIFFERENT DIETS PER RAT

Rat No.	Ragi basal + Horse gram (8) + Sesame (7.75) + ground nut (7.25)		Skim Milk		
	Nitrogen intake (mg)	Nitrogen absorbed (mg)	Nitrogen intake (mg)	Nitrogen absorbed (mg)	
			D. C.	D. C.	
1.	763.0	653.4	85.6	683.1	79.5
2.	749.0	633.6	84.6	553.4	71.3
3.	816.0	695.8	85.3	508.0	69.5
4.	843.0	701.0	83.2	378.4	45.0
5.	765.0	665.2	87.0	537.5	65.2
6.	755	605.4	82.6	640.7	70.0

APPENDIX X

Rat No.	Ragi basal + Horse gram (8) + Sesame (7.75) + ground nut (7.25)		Skin Milk		
	Nitrogen absorbed (mg)	Nitrogen retained (mg)	Nitrogen absorbed (mg)	Nitrogen retained (mg)	
		B.V.		B.V.	
1.	598.1	653.8	91.5	683.1	83.4
2.	586.0	633.6	92.5	553.4	95.5
3.	638.4	695.8	91.8	508.0	98.0
4.	790.9	701.0	95.4	378.4	76.2
5.	617.6	665.2	92.8	537.5	93.8
6.	520.8	605.4	86.0	640.5	85.4

APPENDIX XI

BODY NITROGEN, NITROGEN CONSUMED, NET PROTEIN UTILISATION AND NET DIETARY PROTEIN CALORIES PERCENT OF RATS FED THE TEST DIETS

Diet	Source of Protein	Group	Body nitrogen (g)	Nitrogen consumed (g)	Net protein utilisation	Net dietary protein calories percent
I	-	1	2.352	-	-	-
		2	2.431	-	-	-
II	Ragi basal	1	6.882	5.586	62	7.10
		2	6.032	5.573	65	7.4
III	Ragi basal + Horse gram (11) + Sesame (5) + ground nut (5)	1	7.532	7.041	73	8.6
		2	6.936	6.160	74	8.77
IV	Ragi Basal + Horse gram (8) + Sesame (6.25) and ground nut (7)	1	6.842	6.160	72	10.51
		2	7.381	6.291	64	7.30
V	Ragi Basal + Horse gram (8) + Sesame (7.75) and ground nut (7.25)	1	5.930	8.600	69	9.94
		2	8.007	7.210	78	8.98
VI	Skim milk	1	8.403	7.000	85	10.69
		2	7.469	6.620	76	9.56