EVALUATION OF THE NUTRITIVE VALUES OF PULSE PROTEINS WITH AND WITHOUT SUPPLEMENTATION OF AMINO ACIDS

THESIS

SUBMITTED TO

THE KERALA AGRICULTURAL UNIVERSITY

IN FULFILMENT OF THE REQUIREMENTS

FOR

THE DEGREE OF DOCTOR OF PHILOSOPHY

(FACULTY VETERINARY)

NUTRITION LABORATORY

COLLEGE OF VETERINARY AND ANIMAL SCIENCES

KERALA AGRICULTURAL UNIVERSITY

MANNUTHY :: TRICHUR

OCTOBER, 1975.

E. SIVARAMAN, B. V. Sc., M. Sc.

ACKNOWLEDGEMENT

The author is indebted to:

Dr. C.T.Peter, B.Sc., B.V.Sc., M.Sc., Ph.D., formerly Dean, College of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy for permission to work in the Nutrition Laboratory.

Dr. P.G.Nair, B.Sc., B.V.Sc., M.Sc., Ph.D.,presently Dean, College of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy for the help and good will extended towards the successful completion of the work.

Dr. K.Chandra Menon, G.M.V.C., B.V.Sc., M.Sc., Ph.D., Professor of Animal Husbandry (Retired), College of Veterinary and Animal Sciences, Mannuthy under whose guidance this investigation was carried out.

Dr. P.U.Surendran, M.A., Ph.D., Professor of Statistics for statistical analyses of the results.

Shri. G.Gopinathan Nair, Artist Photographer of the College for taking the microphotographs.

The Indian Council of Agricultural Research New Delhi, for the award of a senior fellowship.

CONTENTS

	Page No.
INTRODUCTION	1-46
Dynamic equilibrium of body proteins	2
Assay methods based on specific physiological functions	3
Protein combinations	7
Amino acid supplementation of proteins	9
Food proteins and their nutritive values	12
Animal proteins	13
Vegetable proteins	23
PRESENT INVESTIGATION	47-51
EXPERIMENTAL	52-76
MATERIALS	52-
Diets	52
Animals	56
METHODS	57
Estimation of essential amino acids in pulse proteins by paper chromatography	57
Estimation of haemoglobin ..	60
Estimation of enzymes	63
Estimation of liver glycogen ..	69

RESULTS 77-279

DISCUSSION 280-306

SUMMARY 307-315

REFERENCES 316-336

APPENDIX

*****

INTRODUCTION

Proteins subserve many physiological functions, long known examples being the respiratory pigments, blood and muscle haemoglobin, serum albumin and globulin which regulate the osmotic pressure of blood and the body fluids and fibrinogen and prothrombin responsible for blood clotting. A fraction of blood protein which is known to have vitally important functions to perform is the globulin which is known to be the precursor of the immune bodies of the blood. Enzymes in digestion and metabolism, hormones in metabolic processes, melanin in pigment formation and to conjugate proteins in detoxicating mechanism, the proteins perform varied and various physiological functions. In addition to these specific functions, proteins perform also the general function of providing energy. This multiplicity of functions is reflected in a corresponding diversity of chemical composition and protein nutrition is dependent upon the supply of the assortment of amino acids required for the synthesis of the wide variety of bodily constituents.

Proteins are in the first place components of all animal tissues, including cell substances and inter cellular fluids, as well as of supporting and protective structures, such as cartilage, skin, hair and nails. All enzymes that have been so far isolated in highly purified and well characterised form and several hormones have been shown to be proteinous in nature. Various antibodies exhibit the properties

INTRODUCTION

Proteins subserve many physiological functions, long known examples being the respiratory pigments, blood and muscle haemoglobin, serum albumin and globulin which regulate the osmotic pressure of blood and the body fluids and fibrinogen and prothrombin responsible for blood clotting. A fraction of blood protein which is known to have vitally important functions to perform is the globulin which is known to be the precursor of the immune bodies of the blood. Enzymes in digestion and metabolism, hormones in metabolic processes, melanin in pigment formation and to conjugate proteins in detoxicating machanism, the proteins perform varied and various physiological functions. In addition to these specific functions, proteins perform also the general function of providing energy. This multiplicity of functions is reflected in a corresponding diversity of chemical composition and protein nutrition is dependent upon the supply of the assortment of amino acids required for the synthesis of the wide variety of bodily constituents.

Proteins are in the first place components of all animal tissues, including cell substances and inter cellular fluids, as well as of supporting and protective structures, such as cartilage, skin, hair and nails. All enzymes that have been so far isolated in highly purified and well characterised form and several hormones have been shown to be proteinous in nature. Various antibodies exhibit the properties

of proteins. Crystalline proteins have been isolated from plants infected with certain virus diseases. The genetic factors in the cell, the genes, are related to the protein portion of the nucleoprotein of the cell. All these present new protein problems in the field of nutrition.

DYNAMIC EQUILIBRIUM OF BODY PROTEINS

The unique functions in the animal body performed by the amino acids arising from protein digestion are all anabolic in nature. According to Whipple (1940) and Schoenheimer (1942) the animal must be regarded primarily as a system of closely and dynamically interrelated proteins. It is, therefore, not surprising that evaluation of a dietary protein with respect to the formation of any particular group of body proteins is found valid for another group of body proteins (Chow et al., 1948, 1950 and Allison, 1949). While each method of assay is capable of furnishing valid data on the ability of a protein to support a specific physiological function such as gain in body weight, regeneration of liver protein or overall retention of nitrogen, no single procedure gives a complete picture of the utilisation of a given protein. The data obtained from a collaborative study sponsored by the Rutgers University have shown that the biological value of a protein depends not only on the physiological state of the animal but also on the particular nutritional task chosen as the criteria. It is obvious that the nutritive value of food proteins should be necessarily assessed in terms of specific physiological functions.

ASSAY METHODS BASED ON SPECIFIC PHYSIOLOGICAL FUNCTIONS

(1) Liver protein Regeneration

This method of evaluation of the nutritive value of a dietary protein was first developed by Campbell and Kosterlitz (1948) and is based on the rate of replenishment of labile liver protein in protein fasted adult rats. Adult rats when fed with a protein-free diet lose considerable part of labile liver cytoplasm in two days and the rate of regeneration of liver protein varies with the quality of the test protein fed to the animals. This method was slightly modified by Henry et al. (1961) who used young rats, adopting a depletion period of 5 days and a repletion period of 10 days. The increase in liver protein per 100 g. initial body weight was taken as the index of the nutritive value. The main criticism levelled against this method is that the liver may not reflect the state of other labile proteins. Further, the method demands several determinations on the excised liver of highly standardised animals.

(2) Rat repletion method

During the course of investigation on the relationship of protein metabolism to antibody production and resistance to infection, Cannon, Humphreys, Wissler and Frazier (1944) devised a fairly rapid method of protein assay. The method involves the production of a biological deficit and the measurement of the replacement value of a test protein. The method has the advantage that variation in protein quality

can be determined in one or two weeks. According to Cannon (1945) the method has shown excellent agreement with the rat growth assay. Wissler et al. (1947) have used this method for the assay of the nutritive values of proteins and protein hydrolysates. They point out that protein depletion stimulates the fabrication of body tissue and blood protein and therefore, in a relatively short period much larger increase in protein than that found in normal growth can be measured. It has been found further, that weight recovery alone is sufficient as a measure of the protein value as this bears a close relationship with regeneration of plasma protein, haemolysin, haemoglobin, liver protein and total carcass protein. In determining the nutritive values of five dietary proteins, viz., whole egg, egg white, lactalbumin, casein and wheat gluten as well as hydrolysates of the two proteins, casein and lactalbumin, Chow et al. (1948), however, failed to observe any co-relation between the commonly used methods of measurements, such as growth and nitrogen balance and those based on liver protein and plasma protein regeneration.

(3) Regeneration of plasma protein and haemoglobin

Whipple and his co-workers (1940) used doubly depleted dogs produced by bleeding during periods of feeding protein-free diet or low-protein diet containing adequate iron. Plasma protein was reduced to 4 to 5 g.% and haemoglobin to 6 to 8 g.%. The capacity of a dietary protein to regenerate

blood proteins was expressed as the ratio between blood proteins regenerated and protein intake. Employing this technique several investigators have clearly established quantitative (Stargiss and Farrar, 1935 and Horn and Whipple, 1939) and qualitative differences (Orten and Orten, 1946; Allison et al., 1949; Halman et al., 1934; Pomneranke, Slavin, Karicher and Whipple, 1935; McNaught, 1936; Melnick and Cowgill, 1937; Madden et al., 1937 and Cox and Muller, 1944) in the ability of proteins to promote the synthesis of plasma proteins and haemoglobin. The results of their studies have shown further that proteins differ also in their relative effect on the formation of haemoglobin and the plasma protein components.

Damodaran and co-workers (Yesoda, 1942, 1945; Damodaran and Vijayaraghavan, 1943; Yesoda and Damodaran, 1947 and Chandran and Damodaran, 1951) found a convenient method of inducing anaemia in rats by the use of phenylhydrazine in their studies on the role of proteins and amino acids in blood formation. These authors have shown that dietary protein, their quality and quantity, profoundly influence haematopoesis. The methods of approach of Whipple and Damodaran and their respective co-workers are similar, namely in producing the deficiency of the specific protein involved in the study, although they differ in the technique employed in producing the deficiency; haemorrhage in the former case and chemical destruction in the latter. The food materials used for comparison were not chemically so well

defined in the experiments of the former group as in those of the latter. The aim of Whipple's experiments was mainly to elucidate the physiological relationship between haemoglobin, plasma protein and cell protein rather than biological evaluation of dietary proteins in terms of haemoglobin regeneration.

(4) Regeneration of liver enzymes

Waino et al. (1953) have reported that the activities of certain enzyme systems in the liver are reduced rapidly, as a result of protein depletion. Williams and Elvehjem (1950) observed that the liver xanthine oxidase activity in rats is sensitive to subtle changes in quality and quantity of dietary protein. A method based on the rate of regeneration of liver xanthine oxidase activity in protein depleted animals for evaluating the quality of a dietary protein was developed by Litwack et al. (1953). Dju et al. (1957) described a the use of the liver xanthine oxidase activity tests for determining the biological value of milk proteins. Relationship between the nutritive value of dietary protein and liver xanthine oxidase activity in young rats as related to growth rate and protein efficiency rates was investigated by Maramatsu et al. (1962). Pigmore et al. (1955) studied the response of the liver enzymes and other proteins to amino acid deficient diets. They found that histidine deficient diet restores xanthine oxidase activity to livers of rats previously depleted of such activity by a non_protein diet. Liver succinic dehydrogenase

is similarly restored by histidine-free and methionine-free rations, but only partially so by lysine free rations. Liver choline oxidase activity of protein depleted rats is restored partially and to about the same extent by the three amino acid deficient diets studied. Liver nitrogen concentration followed the same pattern as succinic dehydrogenase in these studies. Williams (1963) reported that even in severe protein depletion, methionine has a protective effect on liver coenzymes. Mariani et al. (1963) studied the effect of protein depletion on amino acid activating enzymes of rat liver and reported that the activities of the enzymes are considerably increased in the depleted rats and are not affected by variation in energy intake. Sugahara et al. (1963) found a relation between xanthine oxidase in liver and growth of rats when fifteen food proteins were compared. The closest relation between xanthine oxidase and protein quality was obtained with diet containing 15% or 20% protein. Xanthine oxidase in rat liver was almost parallel to the protein score of the diet and is believed to reflect the nutritive value of food proteins.

PROTEIN COMBINATIONS

The primary purpose of a dietary protein is to provide an appropriate pattern of amino acids required for the synthesis of tissue protein. In actual practice, no

single food stuff is consumed exclusively as the sole article of diet. Rations and diets are devised in practical nutrition using many foods. In this process of combining foods into diets, proteins may lose their individuality with reference to their metabolic utilisation. The amino acids of other foods may supplement the amino acids of a given food and vice versa, so that the metabolic utilisation of the combined proteins exceeds the mean utilisation of the individual proteins (Swaminathan, 1967; Bressani and Elias, 1968; Guggenheim and Szmelcman, 1967; Hanafy et al., 1970 and Makdani et al., 1971). In fact, it is possible to combine animal and cereal proteins to give a mixture with a biological value exceeding that of either one of the component foods. By combining foods into diets, if this is done with discrimination, the individuality of the component food proteins as regards metabolic utilisation may be lost. In a sense, it is more important especially in animal feeding, to avoid foods containing poorly digestible proteins than to avoid ones with proteins possessing low biological values. Wheat germ protein is lower in biological value than corn germ protein, but higher in digestibility. In diets, wheat germ protein may thus prove to be a more desirable protein. The heating of cereal protein in the preparation of foods may be a matter of no consequence in practical nutrition, if only the biological value is impaired, because when consumed with

usual proportion of milk proteins this impairment is entirely corrected. But if the digestibility is impaired as in the flaking and toasting of corn there is no known method of food combination that will remedy the situation.

AMINO ACID SUPPLEMENTATION OF PROTEINS

An important development in the field of nutrition has been the practice of supplementing the poor quality proteins with one or more of the limiting amino acids in the proteins concerned in order to bring about profound improvement in the biological value. Based on the studies carried out on rats, pigs and on the chicks to a lesser extent, and on the comparative biological values of feeds and feed combinations, it has been established that feeds of animal origin are superior to feeds of plant origin and that this superiority is primarily due to the amino acid make up of their constituent proteins. Among the animal foods, milk and egg possess the highest nutritive values. Certain animal tissues such as connective tissue and epidermal tissues are of poor quality. Animal foods are generally deficient in sulphur containing amino acids and in isoleucine while most of the cereal proteins are deficient in lysine. Leguminous seeds are deficient in cystine and methionine. Osborne and Mendel (1914) reported that lysine is the limiting amino acid in wheat proteins and that addition of lysine results in

marked improvement in the quality of the proteins for promoting growth. It has been reported that the addition of essential amino acids like lysine and threonine greatly improves the nutritive value of rice proteins (Pecora and Hundley, 1951; Harper et al., 1955; Deshpande et al., 1955; Sure, 1955; Rosenbery and Culik, 1957; Rosenberg et al., 1959 and Desai et al., 1970). The combination produced a growth response in rats three times that obtained with an unsupplemented low protein diet (Pecora and Hundley, 1951). It was found that when rice was supplemented with all the deficient essential amino acids simultaneously, the growth response is more than that obtained by supplements of lysine and threonine. The results indicated that lysine and threonine, are the most deficient amino acids in rice and that they are limiting for rat growth. The accepted view in regard to the beneficial use of threonine is that it overcomes the imbalance of amino acids brought about by the addition of excess of lysine.

Amino acid supplementation is practised by adding the most limiting amino acids in amounts needed to bring the total into balance with the amount available of the second limiting amino acids; if it is desired to supplement also with the second limiting amino acids it is brought into balance with the third limiting amino acid (Waddle, 1958). This approach has been found to be nutritionally sound and economically imperative.

The effect of amino acid supplementation on growth and deposition of fat in the liver of rats was studied by Harper et al. (1955). They found that fat accumulated to the extent of 8 to 10% in the livers of rats fed rice diets. The fat content of liver was normal when 0.4% of L-lysine hydrochloride was included with either 0.24% or 0.5% of DL-threonine. Growth was improved only when both lysine and threonine were included in the rice diets and further improvement was obtained only when a mixture of all the amino acids was added. Deshpande and Harper (1955) found that a rice diet supplemented with 6% of various animal proteins supported an excellent growth rate and maintained normal liver fat level in rats. In short term experiments, retardation in growth caused by including 0.4% lysine hydrochloride in the rice diets was prevented by increasing the levels of leucine, isoleucine, valine and histidine. Rosenberg (1957) stated that the nutritive value of protein of white polished rice can be improved by supplementation with the first limiting amino acid, lysine in amounts sufficient to bring the amino acid into balance with the second limiting amino acid. Rose (1937) has reported that only small amounts of supplementary lysine are necessary to balance this amino acid against the second limiting amino acid. Numerous rat feeding studies demonstrate that lysine is the most limiting amino acid in a wide variety of other cereal grains and the protein quality of such cereals

can be improved by lysine fortification (Hoswe et al., 1965; Bressani and Elias, 1967; Leela et al., 1965 and Narayanaswamy, 1970).

FOOD PROTEINS AND THEIR NUTRITIVE VALUES

Since all plants and animal tissues contain protein, it is evident that all such foods will provide protein in a measure dependant upon the level of the protein in the food itself and upon the quantity of the food ingested. Plant kingdom has the capacity to build up protein from the constituents of the air and soil, using radiant energy of the sun in the process. On the other hand, the animal body cannot synthesise protein from any such simple nutrients but still it continually uses protein in metabolism. Consequently, man as well as all other animals are practically dependent upon plant for food protein supplies. Animal products, to whatever degree they are used as sources of food protein, do so, in the ultimate analysis, as a result of conversion of plant protein into such proteins as are presented in milk, egg and meat. Plants, therefore, are the primary sources of all food proteins and of all animal feed proteins.

Nutritionists often recommend that from 1/3 to 1/2 of the total dietary protein should be derived from high quality animal proteins. The superiority of animal proteins

over vegetable proteins is mainly attributed to the presence in them in large amounts of such essential amino acids as methionine, tryptophane and lysine. It is a moot point whether a certain proportion of animal protein in the diet is indispensable for adequate nutrition, since the ~~part~~ protein in plant tissues is always comprised of several different proteins.

1. ANIMAL PROTEINS

Meat proteins:

The amount of proteins in mammalian muscle tissue irrespective of species, ranges between 12.1 per cent and 21.9 per cent on ~~the~~ fresh weight basis and 73.7 per cent and 88.1 per cent on dry weight basis (Beach, Munks and Robinson, 1943). Beef organs, however, show a wide variation in their protein content: 10.6 per cent in brain and 23.7 per cent in liver on the fresh weight basis and 48.4 per cent in brain and 76.4 per cent in kidney on dry weight basis (Beach et al., 1943). The protein content of chicken meat is found to vary from 20.1 per cent to 30.6 per cent on fresh weight basis. Eight to fourteen per cent of the total nitrogen in meat is reported to be non protein in nature (Beach et al., 1943).

Amino acid composition

The proteins in representative cuts of edible meat such as beef, veal, lamb and pork contain liberal amounts of the essential amino acids in similar proportions (Beach et al., 1943 and Kraybill, 1948). The proteins in beef a organs like brain, liver and kidney are similar in composition, but differ from muscle protein in being poorer in lysine and richer in cystine, tryptophane and phenylalanine (Beach et al., 1943). Meat proteins resemble fish proteins in amino acid composition and hence these can replace each other without affecting the overall nutritive value of the protein (Beach et al., 1943). When compared with egg proteins, meat proteins are higher in histidine and lysine but lower in leucine, isoleucine, valine and methionine (Kraybill, 1948). Meat proteins contain larger amounts of arginine, histidine, lysine and methionine and lesser amounts of leucine, isoleucine and valine than milk proteins (Kraybill, 1948). As a class, meat proteins are rich sources of lysine and methionine.

Nutritive values

Meat proteins are almost completely digestible (Mitchell and Block, 1946). The growth promoting values of the proteins in chicken and beef compare favourably with those of fish proteins (Millers and Fellers, 1948). Beef

proteins are found to be inferior in nutritive value to egg albumin or whole egg proteins but are superior to Casein, wheat gluten or groundnut proteins as judged by growth and maintenance in rats (Ruegamer, Poling and Lockhart, 1950 and Mitchell and Beadles, 1950).

Although the biological value of meat proteins is not as high as that of egg proteins, meat proteins are particularly well suited to supplement the proteins derived from cereals and other vegetable proteins. The supplementary value of meat proteins to pea proteins, egg proteins and cereal proteins has been demonstrated by Lehrer, Woods and Beeson (1947) and Hoagland, Ellis, Haukins and Snider (1947). The value of whole blood protein as a dietary protein source lies in its high lysine content. Haemoglobin is deficient in isoleucine. Fibrin has got a fairly well balanced amino acid composition. It is particularly rich in tryptophane. It has been found that the net protein utilisation of commercial blood fibrin fed at 10 per cent level in the diet of young growing rats is as high as 77 per cent (Forbes and Yohe, 1955).

The two proteins of connective tissues viz., Collagen and elastin are deficient in essential amino acids, excepting arginine and lysine in collagen and phenylalanine, leucine, isoleucine and valine in elastin. Gelatin is a rich source of lysine and arginine, but deficient in most

essential amino acids particularly histidine, sulphur containing amino acids and tryptophane. Gelatin possesses a fairly high digestibility but has a low biological value of 25 to 30 per cent. Gelatin does not promote any growth in rats. Being rich in lysine, gelatin is capable of correcting the deficiency of this amino acid in cereal proteins.

Keratin, as a class, are rich sources of cystine and therefore, it has been suggested that they may be used as supplements to vegetable proteins like yeast proteins which are poor in this amino acid. They are also rich in arginine and threonine. They are low in histidine, lysine, methionine and tryptophane.

2. Milk proteins:

The protein content of cow's milk is 3.0 to 3.4 per cent while the same of buffalo's milk, ewe's milk and goat's milk are 3.4 to 4.2 per cent, 4.7 to 5.6 per cent and 3.7 to 3.8 per cent respectively. About 5 per cent of the total nitrogen of cow's milk and 20 to 40 per cent of the total nitrogen of human milk are accounted for by the non protein constituents, chiefly urea.

Amino acid composition

The whole milk proteins contain almost all the essential amino acids, in adequate amounts and in balanced

proportions (Williamson, 1944; Block and Bolling, 1944 and Hodson et al., 1946). They are particularly rich in the two amino acids, lysine and valine in which cereal proteins are generally low. Casein is deficient in cystine. Lactalbumin is rich in this amino acid and to some extent compensates for its deficiency in casein.

β-lactoglobulin, whey proteins and buttermilk proteins are all well balanced with respect to all the essential amino acids. β-lactoglobulin is particularly rich in lysine (Stokes et al., 1945; Block and Mitchell, 1946 and Block and Bolling, 1951). The proteins of the milk of buffaloe, ewe, goat and sow resemble those of cow's milk in amino acid composition. Human milk proteins have a higher cystine content than cow's milk protein.

Nutritive values

Cow's milk proteins possess a high digestibility, biological value, and growth promoting value (Sundararajan, 1950 and Balasubramaniam, Lily, Mani and Basu, 1955). But they are inferior in these respects to whole egg proteins (Mitchell and Carman, 1926; Summer and Murlin, 1938 and Summer, 1938). In infant nutrition, cows milk proteins are almost equal to human milk proteins. (Gordhan, Levine, Wheatly and Marples, 1937 and Muller and Cox, 1947). While the biological value and digestibility of buffalo's milk

and of goat's milk protein are nearly of the same order as those of proteins of cow's milk, the growth promoting value of goat's milk proteins is comparatively lower (Mitra and Mitra, 1942). For promoting growth in rats, casein is of the same order as beef protein and whole egg proteins, but is inferior to egg albumin.

Milk proteins have been found to supplement ragi proteins and rice proteins, both by themselves and in combination with legume proteins (Swaminathan, 1937 a,b). As supplement to rice protein, milk proteins are superior to pulse proteins (Mitra and Varma, 1947). Milk proteins also supplement proteins of legumes (Basu and Haldar, 1939), of potato (Henry and Kon, 1946), of corn and of wheat (Sure, 1948). Whey proteins supplement cereal proteins in general and wheat proteins in particular (Bell et al., 1954 and Bleeker and Wostmann, 1954). Supplementary relationships have also been demonstrated between butter milk proteins (Sure, 1948) and corn or wheat proteins and between cheese proteins and wheat proteins (Henry and Kon, 1946).

Egg proteins:

The protein content of whole egg on an average is 12 per cent on fresh weight basis and 35 per cent on dry weight basis. The egg white contains five proteins; ovalbumin (75 per cent), ovomucoid (13 per cent), ovomucin (7 per cent),

ovoconalbumin (3 per cent) and ovoglobulin (2 per cent) (Romonoff and Romanoff, 1949). The egg yolk proteins, ovovitellin and ovolivetin are present in 4:1 ratio (Romanoff and Romanoff, 1949).

Amino acid composition

The amino acid composition of whole egg, egg white, egg yolk and of some of the constituent proteins have been worked out by several investigators (Chibnall et al., 1943; Block and Bolling, 1944; Stokes et al., 1945; Dunn, 1947; Hess et al., 1948 and Patwardhan and Vijayaraghavan, 1954). The whole egg proteins are well balanced with respect to all the essential amino acids and are particularly rich in arginine and sulphur containing amino acids (Block and Bolling, 1944). Egg white proteins are richer than egg yolk proteins and whole egg proteins in sulphur containing amino acids, tryptophane, phenylalanine and threonine but not in the basic amino acids (Hess, Kramke, Fritz and Howard, 1948). Whole egg white protein and its principal constituent ovalbumin, are reported to be rich in methionine, while the major yolk protein, ovovitellin, is reported to be rich in arginine, lysine and leucine (Romanoff and Romanoff, 1949).

Nutritive values

Metabolism experiments with rats and human beings have conclusively shown that whole egg protein and egg albumin possess high digestibility (Hawley, Murlin, Nasset and Zymanski, 1948 and Mitchell and Beadles, 1950). Heat treatment is reported to bring about an improvement in the in vitro digestibility of egg white proteins (Harte, 1945). Their digestibility in vivo even in the raw state is of a high order (Narasinga Rao and Patwardhan, 1954). Whole egg proteins possess a higher biological value than the proteins of milk (Mitchell and Carman, 1926; Sumner, 1938; Hoagland and Snider, 1946 and Mitchell and Beadles, 1950), meat (Mitchell and Carman, 1926 and Hoagland and Snider, 1946), Soyabean (Barnes et al., 1945), groundnut (Ruegmer, Poling and Lock hart, 1950) and wheat (Mitchell and Carman, 1924; Barnes et al., 1945 and Mitchell and Beadles, 1950). Similarly egg white proteins possess a higher nutritive value than whole egg proteins or yolk proteins (Hess et al., 1948). The superiority of whole egg proteins over a number of other dietary proteins including milk proteins in human nutrition has also been demonstrated but the superiority of egg proteins over milk protein is reported to be less pronounced in the nutrition of adult human subjects than in young or mature rats (Sumner and Murlin, 1938). While with the growing or adult rats, egg albumin is distinctively

superior to whole egg proteins, human metabolism studies have revealed a slight superiority of whole egg proteins over egg albumin. These reverse effects have been attributed to the higher content in egg albumin of the sulphur containing amino acids in greater proportions for hair growth.

The gross supplementary value of whole egg, egg yolk and egg yolk extracts to the poor rice diet has been demonstrated but not that of egg white (Aykroyd and Krishnan, 1937). Whole eggs have been reported to possess a phenomenal supplementary value to the typical rural diet of Bengal (MacDonald and Boss, 1942, 1945). Soyabean, groundnut and various legumes have been found to give better results when fed in ~~eak~~ combination with egg than when fed alone (MacDonald and Bose, 1945).

Fish proteins

Fish constitutes one of the cheapest and most abundant sources of protein for the human race. The protein content of fresh water fish is reported to vary from 13.7 per cent to 25.2 per cent (Saha and Guha, 1940; Saha and Ghosh, 1941 and Reay et al., 1943), of marine fish from 9.1 per cent to 26.1 per cent (Reay, Cutting and Sherwan, 1943), of 'Koral' meal as high as 93 per cent (Basu and Gupta, 1939) and of

edible white fish flour as high as 89 per cent (F.A.O. World Fish Abstract, 1952). From 7.5 per cent to 17.1 per cent of total nitrogen of most varieties of fish is contributed by non protein nitrogen constituents (Joshi, Master and Magar, 1953).

Amino acid composition

In general, fish protein contains all the essential amino acids in adequate amounts and in balanced proportions (Block and Bolling, 1951) and in this respect resembles other proteins of animal origin (Master and Magar, 1954) and Dunn, Camien, Eiduson and Malin, 1946). As a class, fish proteins are valuable sources of lysine and methionine (Beach et al., 1943; Block and Bolling, 1951 and Master and Magar, 1954). The histidine content of fish protein is highly variable, being higher than 5 per cent (Nielands, Sirny, Sohijell, Strong and Elvehjem, 1949) in some varieties and lower than 1 per cent in certain others (Kelley and Baum, 1953).

Nutritive values

Fish proteins are reported to possess high digestibility, biological value and growth promoting value (Basu and De, 1938 and Basu and Gupta, 1939). Biological values of the proteins in different species of Indian fish are uniformly high (Basu and Gupta, 1939 and Joshi, Master and

Magar, 1953). Fish can replace chicken, pork, beef, lamb or veal as source of animal protein in human diet (Beach, Munks and Robinson, 1943).

Fish proteins are in the same class as chicken proteins (Lepoz-Matas and Fellers, 1948 and Millers and Fellers, 1948). They are inferior to whole egg protein (Sure and Easterling, 1952) but slightly superior to beef proteins (Beveridge, 1947). Fish proteins are about equal to casein (Deuel, Hrubetz, Johnston, Winzler, Geiger and Schnakengerg, 1946) in promoting plasma protein regeneration in depleted rats and are slightly superior to casein and skim milk proteins (Mahalanobis and Roy, 1952) in promoting haemoglobin regeneration.

VEGETABLE PROTEINS

From a nutritional point of view, vegetable proteins, as a class, are generally inferior to animal proteins in many respects. Although the difference in biological value for maintenance between vegetable and animal proteins is not great, the growth promoting values (P.E.R.) of vegetable proteins, in most cases, are less than half of those of animal proteins such as those present in egg, milk, meat or fish. Absence of essential amino acids, especially of methionine, tryptophane, and lysine makes the vegetable

proteins generally inferior to most animal proteins. But evidences are there to show that two or more proteins of vegetable origin can be blended and that they can mutually make up the deficiency and provide a protein of superior nutritive value (Kuppuswami et al., 1958). The experiments of Mendel and Fine (1912) conducted on dogs and human beings show that the proteins of wheat, barley and corn are as digestible per se, as those of meat ie., 93 to 96 per cent. Proteins of soyabean, navy bean, and garden pea are resistant to proteolysis, giving digestion coefficients of 80 to 85 per cent. The proteins of cotton seed are even more refractive to digestion, yielding coefficients of only 67 to 75 per cent. The resistance of legume proteins to digestion in animal may be explained, wholly or in part, by their association with antienzymes. Aqueous extracts of soyabeans and navy beans contain heat labile trypsin inhibiting substances which seem to be responsible for the low digestibility of the protein of raw soyabeans (Ham et al., 1945).

Cereal proteins:

Rice is the staple cereal consumed by more than half the world's population and is the chief source of calories in Asiatic diets (Williams, 1952; West, 1969 and Hisateru Mitsuda and Kyoden Yasumota, 1974). In the case of coarse gm grains, as also in the case of those grains

from which the seed coat cannot be easily removed, the digestibility of protein is of low order (Subramaniam, Narayana Rao, Rama Rao and Swaminathan, 1955).

Protein content

Both the protein content and protein quality in different cereals are influenced by a number of factors, such as those determined by genetics (Woodworth, Leug, and Jugenheimer, 1952), environment (Mitchell, Hamilton and Beadles, 1952; Hutchinson and Martin, 1955; and Frey, 1952) and variety (Sadasivan, Sreenivasan, 1938; Sreenivasan, 1942 and Flynn et al., 1954). A hybrid tetraploid sample of rice has been reported to contain as s much as 13.3 per cent protein (Sampath and Seshu, 1957). By crop selection, a millet has been produced in China which contains over 14 per cent protein instead of the usual 9 per cent. Adolf (1944) and Sampath and Seshu (1957) have shown that rice varieties having long sterile lemna (glumes) have higher protein contents (9.4 to 11.3 per cent) as compared with rice with short sterile lemna (6.5 to 8.7 per cent). McCarrison (1928) observed that rice grown by dry crop method is superior in nutritive value to rice raced as a wet crop. On the other hand, Sreenivasann and Sadasivan (1942) have reported that dry cultivated rice is least effective in promoting growth of young albino rats when

supplied as the sole source of protein and wet cultivated transplanted rice is most effective.

Just as rice makes a contribution of protein in a rice diet, wheat (Triticum aestivum) does it to a larger extent in the wheat diet. The digestibility and biological value of wheat protein have been determined both in rats and human beings. Swaminathan (1937 c) found a biological value of 66 and digestibility of 93 per cent in rats at 5 per cent level. Basu (1946) has reported figures of biological value and digestible coefficient as 53 and 77 respectively for one human subject and 60 and 81 respectively for another. In mixed diets, the biological value of wheat proteins does not difer greatly from that of rice protein so far as the human subject is concerned. In rats, on the other hand, there seems to be some difference in favour of rice. It may be mentioned that the biological values of jowar, bajra and ragi proteins compare favourably with rice protein in the balance sheet method (Acharya, Niyogi and Patwardhan, 1942). The results of the growth method show that they are inferior to both rice and wheat proteins (Swaminathan, 1937 d, e).

Amino acid composition

The amino acid composition of the proteins of rice, wheat, ragi, jowar, barley, oats, corn and of the products of their milling has been extensively investigated (Kik, 1941; Csonka, 1941; Baumgarten, Mather and Stone, 1946; Balasubramaniam et al., 1952; Jansen, 1962 and Howe et al., 1965). Rice, Wheat and corn proteins are all deficient in lysine (Mitchell et al., 1932; Kik, 1940 and Balasubramaniam et al., 1952). In addition, rice protein is deficient in threonine (Pecora and Hundley, 1951) and wheat protein in valine (Sure, 1952). Corn protein is deficient in tryptophane (Csonka, 1939) and also in threonine and methionine (Sure, 1953). Corn gluten meal is reported to be deficient in arginine, lysine and tryptophane (Grau, 1946). The marked amino acid imbalance of zein is due to the presence of glutamic acid, leucine, alanine, proline and phenyl alanine in relatively large amounts (Groschke, Anderson, and Briggs, 1948).

Nutritive values

Extensive investigations have been carried out on the nutritive values of cereal proteins (Chick, 1942; Hawley, Murlin, Nasset and Szymanski, 1948; Schulz and Thomas, 1949 and Mitchell and Beadles, 1950). Rice

proteins possess a far higher growth promoting value than wheat proteins (Sure, 1946; 1947) and also higher biological value than other cereal proteins. Several reports of investigations in India are available to show that the digestibility of rice protein is well over 90 per cent (Patwardhan, 1961). Using the balance sheet method at 5 per cent protein level and rats as experimental animals, Swaminathan (1937) reported for rice protein a biological value of 80. Similar figures for polished and parboiled rice are given by Basu and Basak (1937) and Acharya, Niyogi and Patwardhan (1942). Mitra and Varma (1948) found a biological value of 67 for rice in a diet containing nearly 20 oz. or more of rice and approximately 3 to 4 oz. of pulses per day and this value is identical with that obtained by Basu, Basak and De (1941). Balasubramaniam, Ramachandran, Viswanatha and De (1952) have determined essential amino acids in proteins of rice and of some other cereals. While the proteins of 'Aman' rice promotes good growth in rats (Basu and Basak, 1937) and are highly digestible (Basu and Mukerji, 1936) the proteins of 'Aus' rice do not possess any growth promoting value (Basu and Basak, 1937) and their digestibility is also of a lower order (Basu and Mukerji, 1936).

Addition of limiting essential amino acids has been found to improve the nutritive values of wheat (Jennesken, 1969; Daniel et al., 1968, 1969, 1970; De at al., 1969), wheat gluten (Chang et al., 1969; Gray, 1963 and Somonds and Hegsted, 1973) rice (Chick, 1957; Rosenberg at al., 1959; Desai et al., 1970 and Bressani et al., 1971), barley (Munck, 1966) and corn (Narayanaswami et al., 1970).

Supplementary value

Several workers have studied the effect of supplementation or enrichment of different cereals (Hegsted and Worcester, 1947; Balliete, Decaprio and Sevringhaus, 1950; Westerman, Roach and Stone, 1952; and Westerman, Oliver and May, 1954). Both defatted corn germ and wheat germ effectively improve the nutritive value of wheat flour (Balliette, Decaprio and Sevringhaus, 1950). Corn germ protein is, however, inferior to wheat germ protein in its supplementary value to wheat proteins (Hove, Carpenter and Harrel, 1945). Proteins of milled rice have been reported to possess an excellent supplementary value to the proteins of milled wheat flour and milled white corn meal (Sure, 1953). Buck-wheat (Fagopyrum esculentum) proteins have been found to supplement the proteins of wheat, corn and

rye (Sure, 1955). Mitra and his associates (1948) in their human metabolism studies have found that replacement of part of wheat in poor vegetarian diets by barley, corn, ragi or bajra brings about an improvement in the overall biological value of the proteins in the cereal mixture. The proteins of milled and processed milled rice are improved by the addition of lysine, threonine and methionine and the proteins of enriched milled hard wheat flour, by the addition of lysine, methionine, valine and vitamin B_{12} (Sure, 1955). Effect of supplementation of rice with limiting essential amino acids have been studied by several workers (Harper, 1955; Deshpande, 1955; Howe et al., 1967 and Daniel et al., 1970). Important cereal by-products like the germ, and polishings are of greater value in human and animal feeding. Commercial wheat germ has an average protein content of 29 per cent and this is used in bread making (Grewem and Leclere, 1945 and McCollum, 1945). The high biological value of wheat germ protein is not impaired by such heat processing as is necessary to ~~km~~ make it suitable for human consumption (Hove and Harrel, 1943). Its protein efficiency ratio is less than that of egg (Clark, Hooper and McCord, 1955), equal to that of skim milk powder and higher than that of casein

(jones and Widness, 1946). Rice Germ protein is reported to possess a high biological value and it supports proteins of polished rice (Kik, 1954). According to Kik (1942) the proteins of rice polishing and rice bran possess higher biological values but lower digestibility coefficients than the proteins of milled rice. While the growth promoting value of the proteins of rice polishing is of the same order as that of the whole rice proteins, that of rice bran proteins is slightly less. Work carried out in India has shown that the proteins of rice polishing do not support growth in rats (Basu and Basak, 1937).

Pulse proteins:

The edible leguminous seeds provide an outstanding source of dietary protein to man and animals, more especially to those who can not afford the costly animal foods or have been forbidden from eating flesh, fish or egg by religious taboos. Practically everywhere leguminous plants render direct service to man and animals by supplying available complementary foods and by playing a major role in improving soil fertility. Proteins of leguminous seeds provide certain essential amino acids in which cereal proteins are deficient. Consequently they enhance the overall nutritive values of proteins in a

mixed diet (Phansalkar and Patwardhan, 1956). When included in the processed foods they help to improve the palatability by masking the flavour of the other constituents. Extensive investigations have been carried out in India (Venkata Rao et al., 1964) on the nutritive values of legume proteins and today it is possible to lay down diet schedules based on blends of legumes and cereals as would meet fairly adequately the protein requirements of the body.

Protein content

The protein content of most of the legume seeds falls within the range of 20 to 30 per cent except agathi seeds (Sesbania grandiflora) which contain 68 per cent protein (Subramaniam, Lekshminarayana Rao and Srinivasan, 1952) and lupin seeds (Lupinus luteus) which contain 79 per cent protein (Lugg and Weller, 1944). Bressani (1970) found variation in the protein content of phaseolus vulgaris varieties from central America. Wild inedible legume seeds contain 18 to 47 per cent protein (Pant and Bishnoi, 1967 and Pant et al., 1968). The proteins of legumes are chiefly globulins with certain amounts of albumins in a few cases. The albumin of peas differs from the globulins in having a higher content of

tryptophane and lysine (Danielsson and Liss, 1952; Smith et al., 1959; Powrie, 1961 and Altschul et al., 1966). Protein fractions called vicilin and legumine have been isolated from peas (Danielsson, 1950). Similar protein components are reported in 34 different legume species (Danielsson, 1949). Legumelin has been considered as a third protein constituent. Phaseoline and concanavalin are the terms used to designate respectively the main proteins of the common bean and jack bean. Conglutin is the name applied to the main protein fraction of the lupines. Osborne and Campbell (1897) isolated three distinct globulins from cowpea, namely, vignin, Phaseolin and soluble globulin. Bell and Young (1970) prepared a pea (Pisum Sativum) protein concentrate containing 60 per cent protein and Jaffe and Hanning (1965) and Seidl et al., (1969) isolated a globulin fraction from black bean (Phaseolus Vulgaris). Cajanin and concajanin are the two important globulins in tur dhal (Sundaram et al., 1929).

Amino acid composition

The amino acid composition of the proteins of different legumes has been worked out (Block and Weiss, 1956; Kuppuswamy et al., 1958; Patwardhan and Ramachandran, 1960; King, 1964 and Venkat Rao et al., 1964) and the

available data indicate that pulse proteins are generally good sources of lysine (Baptist, 1954 and Van Etten et al., 1967). In general, methionine is the major limiting amino acid in legume proteins (Kunitz, 1946 and Jaffee, 1950). Tandon et al. (1957) found that soil significantly altered both yield and riboflavin content of kidney beans but the content of nitrogen, methionine, lysine, tryptophane, niacin and thiamine was not found to be affected by soil fertility differences. Bressani et al. (1960) found variation in nitrogen, methionine, tryptophane, thiamine, riboflavin and niacin content between localities for the common black, red and white beans. Crystallisation of phaseolin, the protein isolated from Ukrainian beans (Phaseolus vulgaris) is reported to bring down its methionine content further (Soifer, 1952). White sweet lupin (Lupinus albus) proteins have been reported to contain 2.6 per cent methionine which is rather exceptional for a legume protein (Nehring and Schwerdtfeger, 1951). When the limiting amino acid methionine is added to the diet, the biological value of legume proteins, in general is known to improve (Jaffe, 1949, 1950; Esh and Som, 1952 and Hirwe and Magar, 1953). Alaska field pea protein becomes superior in nutritive value to casein when supplemented with methionine (Woods, Beeson and Bolin, 1943

and Lehrer et al., 1947). Woods et al. (1943) and Lehrer and associates (1947) found that the protein efficiency was doubled and daily gain was tripled when alaska field bean either cooked or raw was supplemented with 0.3 per cent methionine. The proteins of split peas, lentils (Lens culinaris) and red gram (Cajanus cajan) do not produce good growth even when supplemented with methionine (Jaffe, 1949). Supplementation with other amino acids like tryptophane or threonine is also ineffective, but in the presence of methionine, tryptophane and/or threonine the nutritive value is enhanced (Jaffe, 1949 and Braham et al., 1965). Maximum improvement has been obtained in the case of bengal gram and lentils with a combination of methionine, tryptophane and threonine, raising the protein efficiency ratio from 1.3 to 2.3 and 0.7 to 2.6 respectively. Effect of methionine was to improve the pattern of essential amino acids but no effect on protein digestibility has been reported (Bressani et al., 1963). Methionine present in bengal gram is reported (Russel, Taylor, Mehrhof and Hirsch, 1946) to be more rapidly available to the rat than that present in certain varieties of peas, lima beans (Phaseolus lunatus) and snap beans (Phaseolus vulgaris).

Next to methionine, cystine is another general deficiency in legume proteins. However, the proteins of bengal gram, lupin seeds, lentils, and string beans (Phaseolus vulgaris) are reported to contain fair amounts of cystine. The availability of cystine varies among different legumes.

Another amino acid that is found generally limiting in legume proteins is tryptophane (Jaffe, 1949 and Baptist, 1954). The proteins of red gram are particularly very low in tryptophane (Jaffe, 1949, 1950 and Vijayaraghavan and Srinivasan, 1953). The availability of tryptophane from legume protein is reported to be high except in the case of red gram protein (Esh and Som, 1953). Besides the general deficiency of these essential amino acids certain specific deficiences of essential amino acids in particular legumes have been reported like phenyl alanine in horse bean (Mohon and Common, 1950), threonine in horse beans, (Mohon and Common, 1950), subterranean clover seeds (Holmes, 1953) and bengal gram (Giral and Echegoyen, 1949) and valine in peas (Holmes, 1953).

Nutritive values

The proteins of legumes, as a class, are not well balanced in respect of all the essential amino acids and, in general, their biological values are not of high order

(jaffe, 1949). The performance of growing children on predominantly legume diets has been reported to be inferior to their performance on predominantly meat diets (Salmon, 1943). Bressani et al. (1962) found that Vigna Sinensis (cowpea) was of superior nutritive quality than Phaseolus vulgaris and Phaseolus calcaratus. Elias et al., (1964) reported marked differences in protein value in different varieties of cowpea (Vigna sinensis). Gyco and Assenjo (1965) found a positive lactation value for chick peas (Cicer arietinum) pigeon pea (Cajanus cajan) and northern beans (Phaseolus vulgaris). Certain legumes are found to contain protein of fairly high biological value, for instance, Alaska peas (Crosnier and Marguerite, 1951) and bengal gram (Almquist, Mecchi, Kratzer and Grau, 1942). Sulphur containing fertilisers are found to increase the protein efficiency of field peas (Murray et al., 1952). The nutritive values of most legume proteins have been found to be greatly influenced by heat treatment (Dako, 1966; Acharya et al., 1942; Borchers and Ackerson, 1950 and Nitsan, 1971). Heat processing increases the digestibility of legume proteins, removes saponins responsible for the typical bitter tastes in raw legumes and generally improves their flavour. Most of the anti-nutritional or toxic effects of legumes can be partly or wholly eliminated by the proper application of heat.

This effect is manifested by a general enhancement of the nutritive value of the proteins of legumes (Borchen and Ackerson, 1950 and Jaffe, 1949, 1950). Osborne and Mendel (1917) observed that soyabean protein would not support the growth of rats unless cooked for three hours on a steam bath. Since then, many investigators have established the superiority of heat processed soyabean oil meal not only for rats (Mitchell and Smuts, 1932 and Hayward, Steenbock and Bohstedt, 1936) but also for mice (Westfall and Hauge, 1948), chicks (Hayward and Hafner, 1941 and Evans and McGinnis, 1946), turkey poults (Fritz et al., 1947), swine (Becker et al., 1953) and human beings (Lewis and Taylor, 1947). In general these studies have shown that the degree of improvement in nutritive value effected by heat treatment is dependent on temperature, duration of heating, and moisture condition. It has been well established that the addition of methionine and cystine to unheated soyabean meal improves protein utilisation to the same extent as proper heating. The lower nutritive value of unheated soyabean meal is not the result of incomplete digestion of the protein, but is on account of the fact that the methionine is absorbed in a form, or possibly at a site, from which it can not be effectively utilised for growth (Irvin E.Liener, 1958). As soyabean oil meal, the nutritive value of many other legumes is also

improved by proper heat treatment. The widespread distribution of a trypsin inhibitor in legumes provides the most likely explanation for the observation that heating increases the invitro digestibility of a number of legumes. Jaffe (1950) observed that those legumes which have the highest trypsin inhibitor are also those in which the digestibility is most improved by cooking. It has been generally observed that supplementation of uncooked legumes with cystine or methionine markedly improves their nutritive value. Klose, Graeaves and Fevold (1948) on the other hand, have shown that lima bean fractions possessing high antitryptic activity inhibit the growth of rats fed acid hydrolysed casein. Contrary to the beneficial effects of heat observed in most legumes, the nutritive value of field pea is damaged by baking, canning or autoclaving, and this impairment is amenable to supplementation by cystine or methionine. Among the legumes that improve on heat processing, are included the field bean (Dolichos lablab), navybean (Phaseolus vulgaris), pintobean (Phaseolus vulgaris), Jackbean (Canavalia ensiformis), Velvet bean (Macuna deeringianum), adsukibean (Phaseolus angularis), horse bean, horsegram and khesari dhal (Lathyrus sativus). The partridge pea (Chamaecrista fasiculata), guarbean (Cyanopsis psoraloides), lespedeza (Lespedeza stipulacea) and the common vetch (Vicia sativa)

are those that do not improve on heat treatment. There are a number of reports in the literature to the effect that the nutritive value of pea proteins is impaired as a result of heat processing (Woods, Beson and Bolin, 1943; Everson and Heckert, 1944; Richardson, 1948 and Murray, 1948); but there are also reports to the contrary (Achary et al., 1942 and Esh and Som, 1952). Conflicting reports also exist regarding the effect of heat processing on the biological value of proteins present in a number of other legumes such as Bengal gram (Acharya et al., 1942; Esh and Som, 1952 and Hirwe and Magar, 1953) lentils, (Jones and Murphy, 1924; Acharya et al., 1942; Esh and Som, 1952 and Hirwe and Magar, 1953) green gram, blackgram, red gram (Subha Rao and Subrahmajyam, 1950; Esh and Som 1952 and Hirwe and Magar, 1953) and cowpeas (Richardson 1948; Brochers and Ackerson, 1950 and Sherwood, Weldon and Peterson, 1954). It has been reported that cooking cowpea makes no difference to the growth promoting value of its proteins in some samples but it has a beneficial effect in some others (Sherwood et al., 1954). Parching improves the nutritive value of the proteins of bengal gram, green gram, horse gram and dried peas (Acharya et al., 1942). Many legumes contain trypsin inhibitors, which in most cases are heat labile, but no correlation has been observed

between the effect of autoclaving on the nutritive value of proteins and the presence or absence of trypsin inhibitors in raw legumes (Brochers and Ackerson, 1950). In most instances, when heat treatment does produce a positive effect, it seems to make little difference whether the legumes are cooked in water, autoclaved or parched. Notable exceptions, however, are Phaseolus vulgaris and Dolichos lablab which require preliminary soaking prior to cooking or autoclaving in order to eliminate completely the toxicity of the raw bean (Jaffe, 1949). That the trypsin inhibitor of Soyabean is destroyed by heat is amply supported by experimental evidence and there appears to be an inverse correlation between the trypsin inhibitor content of partially heated soyabean meals and their nutritive values (Westfall and Hauge, 1948). The heat lability of trypsin inhibitors from other legumes has not been investigated to any great extent, but the available information indicates that some of those inhibitors, such as those from the lima bean (Taubear, Harshaw, and Wright, 1949) Phaseolus vulgaris (Sohonie and Bhandarkar, 1954) and Faba vulgaris (Sohonie and Bhandarkar, 1954 and Kothari and Sohonie, 1960) may be more heat stable than the soyabean trypsin inhibitor. The increased digestibility of cooked legume, as measured

in vitro and in vivo, is presumably due to the destruction of trypsin inhibitors contained in them. The haemagglutinin of soyabean is destroyed by autoclaving, and the improvement in nutritive value effected by heat parallels the extent to which the haemagglutinin has been destroyed (Liener and Hill, 1953). Partial heat inactivation of the purified haemagglutinin from Phaseolus vulgaris shows a parallel destruction of toxicity and haemagglutinating activity (Jaffe, 1961).

Nutritive quality of legume proteins is known to improve to a marked extent when supplemented with the limiting amino acids (Borchers, 1962; Bressani et al., 1963; Parthasarathy et al., 1964; Sreenivas et al., 1964; Venkita Rao et al., 1964; Devadas et al., 1967; Venkat Rao et al., 1971 and Vijayalekshmy et al., 1972). Since methionine is the major limiting amino acid in most legume proteins, its addition to the diet has been found to enhance the nutritive value of legume proteins to a considerable extent (Jaffe, 1949, 1950; Esh and Som, 1952 and Braham et al., 1965). The nutritive value of alaska field pea is increased almost to that of casein when supplemented with methionine (Woods, Beeson and Boling, 1943). Jaffe (1949) reported a marked improvement in the nutritive value of red gram, split pea and lentil, when

tryptophane and threonine are added along with methionine. Sherwood et al. (1954) observed a significant increase in the growth rate of rats when fed a cowpea diet supplemented with methionine. It has been observed that cowpea flour incorporated in a diet at 18 per cent protein level, on nitrogen basis promotes higher growth response in rats than tur dhal and in this respect, almost similar to Casein (Sivaraman, 1967). But on the other hand both cowpea and tur dhal proteins supplied through a synthetic diet at 10 per cent protein level did not support growth and maintain nitrogen balance. Supplementation of these two pulse proteins with both methionine and tryptophane promoted growth, and maintained positive nitrogen balance and showed significantly higher biological value (Sivaraman, 1969).

Supplementary value

Since the general pattern of essential amino acids in cereal and legume proteins is dissimilar, they are capable of supplementing each other with the result that cereal-legume mixtures contain proteins of superior nutritive value (Swaminathan, 1937, 1938; Murray, 1948; Adolf et al., 1955 and Phansalkar and Patwardhan, 1956). Supplementary relationships have been observed between the proteins of bengal gram and parboiled wheat (Adolf, Shammar and Halaby, 1955), between the proteins of horse beans and corn (Chen

and Wang, 1943) and between the proteins of peas and cereal germ (Beeson, Lehrer and Woods, 1947). Investigations have shown that the proteins in legumes such as bengal gram, black gram, green gram and red gram supplement wheat proteins, jowar proteins and bajra proteins but not rice proteins (Phansalkar, Ramachandran and Patwardhan, 1957). As judged by human metabolism studies, legume proteins are inferior to milk proteins in supplementing rice proteins (Mitra and Varma, 1947). Esselbaugh et al., (1952) found in human subjects, at low levels of protein intake, that the egg replacement value of pea was 95.1 per cent and 100 per cent for methionine supplemented pea protein. Hansen et al. (1960) and Brock (1961) found a significantly higher nitrogen retention when corn was fortified with pea flour. Metabolic studies carried out by Matoth et al. (1968) in infants showed that the vegetable protein mixture containing legumes compared favourably with cow's milk diets. Several workers have obtained higher nutritive values for combination of cereal legume mixtures (Tasker et al., 1962; Chaves et al., 1962; Panemangalore et al., 1967; Desai et al., 1968; Elias et al., 1969; Hanafy et al., 1970 a, b, c, and Daniel et al., 1970).

Protease inhibitors

The physical and chemical properties, pharmacological effects and nutritional aspects of protease inhibitors have been largely studied and widely reported (Kunitz, 1945, 1946, 1947 a, b, 1948; Liener, 1950, 1958, 1962; Brochers, 1965; Rackis, 1965; Birk, 1968; Mickelsen and Young, 1966; Vogal et al., 1966, 1966 a and Back and Mammen, 1968). However, several areas in the field are yet to be explored.

The fairly widespread distribution of trypsin inhibitors in legumes provides the most likely explanation for the observation that heating increases the digestibility of many leguminous proteins (Osborne and Mendel, 1917; Waterman and Jones 1921; Jaffe, 1950; Carrol et al., 1952; Liener, 1958, 1962; Barnes et al., 1962, 1965; Borchers, 1962 and Kakade and Evans, 1965). It may, however, be noted that not all legumes which have trypsin inhibitors have their nutritive values enhanced by heating (Brochers and Ackerson, 1950 and Jaffe, 1950). Different methods of processing of legumes have been found to have effect on protease inhibitors (Liener, 1962). Most of the protease inhibitors are destroyed by heat treatment and thus their nutritive value is enhanced (Brochers et al., 1947; Liener, 1962; Smith et al., 1964; Rackis, 1965 and

Kakade and Evans, 1966). The easiness with which the inhibitors are removed gained popularity for the legumes as a staple component of the diet.

Most of the work in regard to the effect of heat treatment on the nutritive value of legumes has been confined to soyabean (Osborne and Mendel, 1917; Hayward and Hafner, 1941; Melnick et al., 1946; Evans and McGinnis, 1948; Liener et al., 1949; Bouthelet et al., 1950; Carol et al., 1952; Liener, 1958; Borchers, 1962; Saxena et al., 1963; Nitsan, 1965 and Nesheim and Jarlick, 1966). Comparatively very little is known in this regard in respect of other legumes; much less so as applied to cowpea and tur dhal.

PRESENT INVESTIGATION

PRESENT INVESTIGATION

Proteins subserve many physiological functions. Pulses constitute an important source of protein in this regard. Besides being an excellent source of vegetable protein for human population, leguminous crops also provide good fodder for livestock. From a nutritional point of view pulses not only supplement cereals (Beeson et al., 1947; Adolf et al., 1955; Baptist, 1956 and Bressani et al., 1962) but on account of the differences in the amino acid composition of the constituent proteins they also supplement each other (Phansalkar and Patwardhan, 1964 and Daniel et al., 1968). Although a great deal of work on the nutritive values and supplementary values of a wide variety of pulses have been carried out (Bressani and Valiente, 1962 and Venkat Rao et al., 1964), comparatively very little work has been done in this regard with cowpea (Vigna catjang) and tur dhal (Cajanus cajan), two important sources of nitrogenous foods for man and livestock. Most of the work carried out in regard to the nutritive values of proteins have been confined to growth response chosen as the sole criterion. It has been shown (Mitchell, 1924 and Allison, 1955) that the biological value of a protein differs from one physiological function to another. It is, therefore, essential that the nutritive value of a protein or a protein source is evaluated

in terms of specific physiological functions. Although it has been recognised that pulses represent an important source of protein, it has been reported that several of them contain protease inhibitors which depress growth response of animals. In pursuance of these considerations detailed in the introduction, an investigation was carried out to assess the nutritive values of cowpea (Vigna catjang) and tur dhal (Cajanus cajan) - the two indispensable pulses in the dietary of human beings in this part of the country, in terms of specific physiological effects such as growth, nitrogen retention, red cell, haemoglobin and plasma protein concentrations, and liver protein and liver fat contents. For this work the author was awarded M.Sc. degree (Nutrition) by the University of Kerala in 1969.

The following were the significant inferences drawn from this study (Vide the reprint and the summarised results presented as appendix at the end of the present thesis):

(1) Raw cowpea flour incorporated in a diet at 18 per cent protein level on nitrogen basis promotes on feeding for a period of 28 days a significantly higher growth response in rats than raw tur dhal flour supplied at the same protein level.

(2) The growth rate obtained with cowpea flour at

18 per cent protein level is essentially the same as that obtained with the control diet containing 18 per cent casein as the sole source of nitrogen.

(3) In the growing rats, both cow pea and tur dhal each at 18 per cent protein level in the feed produce the same haematopoietic response but in the adolescent animals, as judged by the phenylhydrazine amaemia technique, the two pulse proteins are less efficient than casein for promoting haemoglobin formation.

(4) Cowpea protein and tur dhal protein, when each fed at 10 per cent level through synthetic diets do not support somatic growth in young albino rats and register negative protein efficiency ratios (P.E.R.).

(5) On supplementation with the limiting essential amino acids, methionine and tryptophane, the two pulse protein diets bring about positive growth response and register high P.E.R. values.

(6) Methionine and tryptophane supplementation of cowpea protein brings about a significantly higher growth response in animals than that obtained on the control diet and on the amino acids supplemented tur dhal protein diet.

(7) Supplementation with either methionine or tryptophane or both or their withdrawal from the diets

during the 5th, 6th and 7th week of experimentation brings about noticeable changes in the body weights of the animals.

(8) The most limiting essential amino acid in cowpea protein for growth in the rat when fed at 10 per cent level on nitrogen basis appears to be methionine. Both methionine and tryptophane are limiting in this regard in tur dhal protein.

(9) At 10 per cent level, both cowpea protein and tur dhal protein support positive nitrogen balance and promote nitrogen retention. Supplementation with the limiting essential amino acids, methionine and tryptophane, brings about significantly higher nitrogen balance and per cent nitrogen retention in animals receiving the pulse proteins, the effect produced in the case of the cowpea protein diet being comparable with that observed in the case of the control diet and more pronounced than that obtained on the tur dhal protein diet.

(10) Maintenance of body weight or gain in weight of rats does not appear to bear any relationship with nitrogen balance or with retention of nitrogen expressed as the percentage of intake. The attainment of positive nitrogen balance does not seem to be an indication that the quantitative requirements of nitrogen for optimum growth are satisfied.

(11) Cowpea protein and tur dhal protein possess low biological values but on supplementation with methionine and tryptophane, significantly higher and almost identical biological values are obtained, the values approaching nearly the biological value obtained for casein.

(12) Methionine and tryptophane do not seem to exert any marked influence over liver protein content. A reduction in liver fat content probably attributable to the lipotropic effect of methionine is observed in animals receiving the amino acid supplemented pulse diets.

(13) Among liver, kidney, spleen and heart, only the livers of animals receiving the pulse protein diets show slight structural alterations.

(14) Supplementation of methionine and tryptophane to the pulse protein diets promotes the regeneration of red cell and haemoglobin in rats recovering from phenyl-hydrazine anaemia although not at a rate comparable to that obtained on the control diet containing 10 per cent casein.

(15) Both methionine and tryptophane appear to be limiting amino acids in cowpea protein and tur dhal protein for red cell and haemoglobin formation in the rat.

The significance of the observations made above prompted further research and accordingly an investigation comprising of three series of experiments was carried out during the present investigation in order to (1) assess the comparative effects of feeding diets with raw and autoclaved cowpea and diets with raw and autoclaved tur dhal each containing 10 per cent protein on nitrogen basis on growth response and such other physiological functions as nitrogen retention, red cell, haemoglobin and plasma protein concentrations, liver protein and liver fat contents, glutamic-oxalo acetic transaminase and glutamic-pyruvic transaminase levels in serum and liver and internal organ weights, (2) evaluate the influence of supplementation of these diets with the limiting amino acids, methionine and tryptophane, on the various physiological functions and (3) determine the relative merits of feeding autoclaved cowpea and tur dhal diets at higher levels of protein intake (18 per cent) on growth response, red cell and haemoglobin formation and reproduction and lactation.

E X P E R I M E N T A L

EXPERIMENTAL

Three series of experiments were carried out using growing albino rats as experimental subjects, in order to assess (1) the comparative effects of feeding raw and autoclaved cowpea and tur dhal incorporated in the diets each at 10 per cent protein level on nitrogen basis on specific physiological functions such as growth, protein efficiency values, nitrogen balance, blood formation, liver fat, liver protein and liver glycogen contents and liver and serum enzymes, (2) the relative merits of these diets on feeding on the various physiological functions on supplementation with methionine and tryptophane and (3) the beneficial effects observed in respect of the various physiological functions when the autoclaved pulses are incorporated in the diets at 18 per cent protein level on nitrogen basis. In this series of experiments were also included studies carried out to evaluate the comparative effects of the diets on the reproductive and lactative performance of the animals.

MATERIALS

Diets

The compositions of the isoproteimic test diets (on nitrogen basis) used in the first and second series

of experiments (Diets A, B, C, D and E and Diets F, G, H and I respectively) are given in Tables 1 and 2 respectively. Diet C served as the control. Diets A and F and Diets D and H contained respectively 51.0 parts of raw cowpea and autoclaved cowpea. Diets B and G and Diets E and I contained respectively 49.0 parts of raw tur dhal and autoclaved tur dhal. The compositions of the isoproteimic test diets used in the third series of experiments (Diets J, K and L) are given in Table 3. Diet L served as the control. Diets J and K contained 70.0 parts of autoclaved cowpea flour and 70.0 parts of autoclaved tur dhal flour respectively. Seventy parts of cowpea flour and 70.0 parts of tur dhal flour (raw as well as autoclaved) supplied 15.0 and 14.1 parts of protein (N x 6.25) respectively. The compositions of the isoproteimic test diets (Diets M, N, O, P and Q) used for studies on the reproductive and lactative performance of rats are set out in Table 4. Diet O served as the control. The protein level was made up to 18 parts by the addition of the required amount of protein isolated from cowpea and tur dhal respectively. The vitamin mixture incorporated in the diets contained the following per kilogram of diet:

Thiamine hydrochloride	20 mg.
Riboflavin	20 mg.
Pyridoxine hydrochloride	20 mg.

Calcium pantothenate	60 mg.
Nicotinic acid	100 mg.
Ascorbic acid	200 mg.
Biotin	4 mg.
Folic acid	10 mg.
p-aminobenzoic acid	400 mg.
Inositol	800 mg.
α-tocopheryl acetate	100 mg.
Vitamin B_{12}	150 μg.
Choline chloride	2 g.
Vitamin A	5000 U.S.P. Units
Vitamin D_2	500 U.S.P. Units

In all the experiments, food and water were provided to the animals ad libitum and daily food intakes were recorded.

Proteins:

Preparation of casein

Casein was prepared from skimmed milk powder according to the procedure described by Cohn and Hendry (1932) as described below:

Skimmed milk powder (5 kg) was made into a uniform paste with water and diluted to about 30 liters. N/20 HCL was added slowly through a capillary tube with vigorous methanical stirring till the pH was 4.6. The precipitate

was allowed to settle overnight and the clear yellowish liquid at the top was siphoned off. The casein was filtered through muslin and then pressed tight within folds of drill cloth in a filter press. It was stirred up with distilled water, filtered and pressed, and the process was repeated three or four times.

The washed casein was suspended in water and N/10 sodium hydroxide was slowly added with vigorous stirring till the pH value reached 6.3. Local excess of alkali was carefully avoided during the addition of the alkali. The sodium caseinate solution was filtered through a thick pad of paper pulp and the casein in the solution was precipitated by the addition of N/20 acid as before. The precipitated casein was allowed to settle and after decanting off the supernatant liquid it was filtered through muslin, pressed free from as much of the liquid as possible, and washed repeatedly with distilled water each time taking care to remove as much of the liquid as possible, before more water was added. When the washings were free from chloride, the protein was again pressed free from most of the water. The wet product when dried with acetone weighed nearly one kg. and contained about 12 to 15 per cent moisture.

Preparation of pulse proteins

The two pulse proteins required for incorporation

in the diets were prepared from Cajanus cajan (Tur dhal) and Vigna catjang (Cowpea) flour respectively by extraction with 3.5 per cent sodium chloride solution, precipitation by full saturation with ammonium sulphate, redissolving the precipitate in water and heat coagulating at 100° C. The heat coagulated proteins were washed free from ammonium sulphate and dried with acetone. The two pulse proteins were analysed for amino acid composition by paper chromatography.

Pulses:

Cowpea (vigna catjang) and tur dhal (Cajanus cajan) required for the study were purchased locally, air dried, pulverised in a wiely mill and stored in desicators. For purpose of incorporation in diets (Diets D, E, H, I, J, K, P and Q), each flour was autoclaved at 15 lbs. pressure for 30 minutes.

Starch:

Corn starch used in the preparation of diets was obtained from Messrs. Vora Brothers, Bombay.

Amino acids:

The amino acids (L-Methionine and L-Tryptophane) used for incorporation in the diets (Diets F, G, H and I) were the products of E. Merk, Germany.

Animals

Albino rats of the college stock colony formed the subjects for the study. In the first series of experiments 50 young rats weighing on an average 53 g. were used, the animals being distributed into five groups of 10 animals each. In the second series of experiments 40 young rats weighing on an average 53 g. were employed, the animals being distributed into four groups of 10 animals each. In the third series of experiments 24 rats weighing on an average 48 g. were used, the animals being distributed into three groups of 8 animals each.

For studies on the reproductive and lactative performance of rats, 50 adult female rats, distributed into five groups of 10 animals each, were maintained on diets M, N, O, P and Q respectively. The animals were kept for breeding by leaving the females with the males for 2 weeks, males of proved fertility being interchanged between females every alternate day. The criteria used for reproduction of female rats were; (1) number of animals that gave birth to young, (2) number of young born per rat and (3) average weight of young at birth. The criteria for lactation were: (1) percentage of young weaned on the 21st day and (2) average weaning weight of young.

Rats were always distributed into groups as evenly as possible in regard to weight and sex. In all series of

experiments except in those employed for reproduction and lactation studies, the animals were housed in individual cages with raised screen bottoms. For reproduction and lactation studies 3 female rats were maintained in a cage.

Experimental animals were weighed once a week. Red blood cell and haemoglobin concentrations were estimated at weekly intervals. Plasma protein, liver and serum enzyme activity, liver fat and liver protein content, and internal organ weights were determined at the end of the 4th week of experimentation when the animals were sacrificed.

In the first and second series of experiments, nitrogen balance was determined during the last 4 days of experiment. Carmine was used as faeces marker and thymol and sulphuric acid as urine preservatives. Duplicate samples of faeces and urine were analysed for nitrogen. Urine and faecal samples collected during the metabolism trials were analysed by conventional methods (A.O.A.C. 1960).

METHODS

I. Estimation of essential amino acids in the pulse proteins by paper chromatography

Preparation of hydrolysate:

The samples (300 mg. each of cowpea flour and cowpea protein and 253.5 mg. of tur dhal flour and 146.6 mg. of

tur dhal protein) in duplicate were hydrolysed with 12 ml. of 6 N. HCL for 24 hours at 105° C in sealed test tubes. After hydrolysis, excess acid was removed by repeated evaporation and the hydrolysates were made upto 5 ml. with 10% isopropyl alcohol as preservative. These hydrolysates were used for analysing the essential amino acids except tryptophane by paper chromatography (Hanumantha Rao and Subrahmaniam, 1970).

Chromatographic analyses and solvent system

The made up solution was analysed chromatographically using one dimensional descending technique. Whatman No.1 filter papers washed thoroughly with N/100 hydrochloric acid and water and later dried, were used for chromatographic runs. The solvent system used was Butanol: acetic acid: water (4:1:5).

Chromatographic grade Whatman No.1 filter paper was cut into 9" x 22.5" size. A pencil line was drawn across the paper 3" from one end of the paper, after showing the direction marked on the box. Ten µl of cowpea flour, 5 ul of cowpea protein and 10 µl of tur dhal flour and tur dhal protein hydrolysates were spotted on the line at 1.5" apart along with the standard amino acid solution made from pure amino acids, using micropipettes. The sample impregnated paper was hung in the air tight chromatographic chamber

and allowed to get saturated with the solvent vapour from the aqueous phase of the solvent kept in the chamber. The solvent was added to the trough through the opening in the lid and closed air tight. The chromatograms were run for 18 hours. The papers were air dried and the chromatograms were run for a second time with fresh solvent. The papers were air dried and uniformly sprayed with 0.4% ninhydrin solution in 95% acetone. After drying the chromatograms were kept at 65°C for 30 minutes for full colour development. The colour bands were cut out and the colour eluted with 5 ml. of 75% ethyl alcohol containing 0.2 mg. of copper sulphate by equilibrating the cut bands with this solvent for 30 minutes. Care was taken to avoid contamination of paper during handling. The colour intensity of the extracts was determined using 'spectronic 20' at 540 mμ. The amino acid concentration in the hydrolysates were calculated using the values for standards.

II. Estimation of blood values

Blood samples for the determination of red cell and haemoglobin were obtained by snipping the tail of the rats.

(1) Red blood cell: Red cell counts were made using the improved Neubauer counting chamber with 1 in 200 dilution of blood using Hayem's solution as the diluting fluid.

(2) Estimation of haemoglobin

An acid haematin repeatedly checked against samples of blood, the haemoglobin content of which had been obtained by the method of Wong (Wong, 1928) was used as the standard for haemoglobin determinations.

Standard acid haematin solution:

A large sample of ox blood was collected in an oxalated bottle and the haemoglobin concentration was calculated from the estimation of iron according to the method of Wong (1928). The blood was diluted with 0.1 N. hydrochloric acid in a volumetric flask so that the resultant haemoglobin (acid haematin) concentration was 3%. Thus, if the haemoglobin concentration was 14.2%, 21.2 ml. $\left(\frac{100 \times 3}{14.2}\right)$ were diluted to 100 ml. with 0.1 N. hydrochloric acid. The 3% solution thus obtained was well mixed and kept in a refrigerator. From this stock solution, the comparison standard was prepared every week by diluting 2.5 ml. to 100 ml. with 0.1 N. hydrochloric acid, making an acid haematin solution equivalent to 0.075% haemoglobin.

Procedure:

0.05 ml. of blood from a freely flowing source were measured into exactly 10 ml. of approximately 0.1 N. hydrochloric acid. The blood was rinsed out thoroughly by sucking up the acid and blowing out several times.

If the blood appeared to be low in haemoglobin, twice the volume of the blood was collected. It was mixed well and let stand for atleast one hour. Then the solution was compared in a 'Spectronic 20' with the standard solution prepared as above.

Calculation: $\frac{\text{Reading of the unknown}}{\text{Reading of standard}} \times 0.075 \times \frac{100}{0.05} \times \frac{10}{100}$

= g. of haemoglobin/100 ml. of blood.

Wong's method (Wong, 1928)

Principle:

The iron is detatched from the haemoglobin melecule by treatment with strong sulphuric acid in the presence of potassium persulphate without heating. After removal of protein by sodium tungstate, iron is determined colorimetrically, in the filtrate by thiocyanate reaction.

Procedure:

0.5 ml. of blood was transferred accurately with a micro-pipette into a 50 ml. volumetric flask. To this, 2 ml. of iron free concentrated sulphuric acid were added. It was mixed and 2 ml. of saturated potassium persulphate solution were added. After mixing and diluting to about 25 ml. with distilled water 2 ml. of 10% sodium tungstate solution were added. After cooling, it was made up to volume and mixed. Then it was filtered into a dry beaker. Prepared a standard

in a second 50 ml. volumetric flask by adding to about 25 ml. of distilled water in the flask the following; 2 ml. of concentrated sulphuric acid, 2 ml. of saturated potassium persulphate solution and 2.5 ml. of standard iron solution, containing 0.1 mg. ferric iron per ml. Cooled to room temperature, diluted to the mark and mixed. For photometric measurements prepared a blank with 2 ml. of concentrated sulphuric acid, 2 ml. of saturated potassium persulphate and water. Ten ml. of unknown, standard and blank, if necessary, were pipetted into separate test tubes. To each added 0.5 ml. of saturated solution of potassium per sulphate followed by 2 ml. of 3 N. potassium thiocyanate solution. Mixed thoroughly and compared in a 'spectronic 20' calorimeter.

Calculation: $\frac{\text{Reading of unknown}}{\text{Reading of standard}} \times 0.25 \times \frac{100}{0.5} \times \frac{1}{3.4}$

= g. of haemoglobin per 100 ml. of blood.

The value 1/3.4 represents the fact that 1 g. of haemoglobin contains 3.4 mg. of iron. If this factor is omitted in the calculation the result gives mg. of total iron in 100 ml. of blood.

Reagents

Saturated potassium persulphate - 100 ml. of distilled water were added to 7 g. of pure potassium persulphate in a glass stoppered bottle. Undissolved excess settles and

compensates for loss by decomposition.

3 N. potassium thiocynate - 14.6 g. of potassium thiocynate were dissolved in 500 ml. of distilled water and filtered if necessary. To this, 20 ml. of acetone were added to improve keeping quality.

10% sodium tungstate - 100 g. of reagent grade iron free sodium tungstate were dissolved in water and diluted to one litre.

Standard iron solution - 0.702 g. of reagent grade crystalline ferrous ammonium sulphate (Mohr's salt) were weighed out accurately and dissolved in about 50 ml. of distilled water. To this solution, 20 ml. of a 10% iron free sulphuric acid were added and diluted to a litre. Each ml. of this solution would contain 0.1 mg. of iron.

(3) Estimation of plasma protein

Blood samples for estimation of plasma protein were withdrawn by heart puncture into citrated tubes. Plasma protein was estimated by Kjeldahl method (N x 6.25). Non-protein nitrogen was not estimated.

III. Estimation of enzymes

Preparation of tissue homogenate

Each liver sample was homogenised in a potter-Elvehjem

glass homogeniser with 10 to 20 times its volume of ice cold physiological saline, filtered through 4 layers of muslin cloth, filtrate collected in labelled test tubes and preserved in the freezing chamber of a refrigerator.

(1) Glutamic-oxaloacetic transminase activity in liver - Method as cited by Bergmeyer (1965)

Principle

GOT catalyses the reaction:

L-Glutamate + Oxaloacetate $\rightleftharpoons$ L-aspartate + α-Oxoglutarate

The activity of the transaminase is measured by the increase of oxaloacetate with time as the reaction proceeds from right to left. After a fixed time, the 2,4-dinitrophenyl hydrazone of the reaction product of oxaloacetate, is determined spectrophotometrically in alkaline solution. Some of the oxaloacetate decarboxylates spontaneously to pyruvate. The assay mixture therefore contains oxaloacetate, pyruvate and α-oxoglutarate, all of which form 2,4-dinitrophenyl hydrasones with absorption maxim at different wave lengths. Measurement is made at a wave length higher than the wave length of its maximum absorption since this allows the greatest differentiation between the optical densities of the three hydrazones.

Reagents

(i) Substrate buffer solution (0.1 M phosphate buffer, pH 7.4, 0.1 M. L-asparate, 2 x 10^{-3}M α-oxoglutarate): Dissolved 1.50 g. K_2HPO_4, 0.20 g. KH_2PO_4, 0.030 g. α-oxoglutaric acid and 1.32 g. L-aspartic acid in less than 100 ml. of water. Adjusted the pH to 7.4 with 0.4 N sodium hydroxide solution and diluted to 100 ml.

(ii) Ketone reagent (10^{-3}M 2,4-dinitrophenyl hydrazine): Dissolved 20 mg. of 2,4-dinitrophenyl hydrazine in 1 N hydrochloric acid and made up to 100 ml.

(iii) Sodium hydroxide (0.4 N): Dissolved 16 g. of sodium hydroxide in water and made up to 1000 ml.

(iv) Sodium pyruvate (2 x 10^{-3}M): Dissolved 22 mg. of sodium pyruvate in water and made up to 100 ml.

Procedure

Experimental and blank tubes were prepared as follows:

Experimental	Blank
1 ml. of substrate buffer solution	1 ml. of substrate buffer solution
+	
0.2 ml. homogenate. Mixed by inversion and incubated for exactly 60 minutes	Did not incubate
Added 1 ml. of ketone reagent	Added 1 ml. of ketone reagent followed by 0.2 ml. homogenate

Allowed to stand for 20 minutes at room temperature. Mixed into the experimental and blank tubes, 10 ml. each of 0.4 N sodium hydroxide solution. After 5 minutes the optical density of the experimental solution was read against the blank in a Bausch and Lomb 'Spectronic 20' colorimeter at 546 mμ. A standard curve was prepared with values given in table (Bergmeyer, 1965) and unknown values were read from the curve (Fig. 1).

Optical density	Units
0.020	8
0.040	16
0.060	24
0.080	32
0.100	40
0.120	49
0.140	59
0.160	71
0.180	83
0.200	100
0.220	118
0.240	140
0.260	167

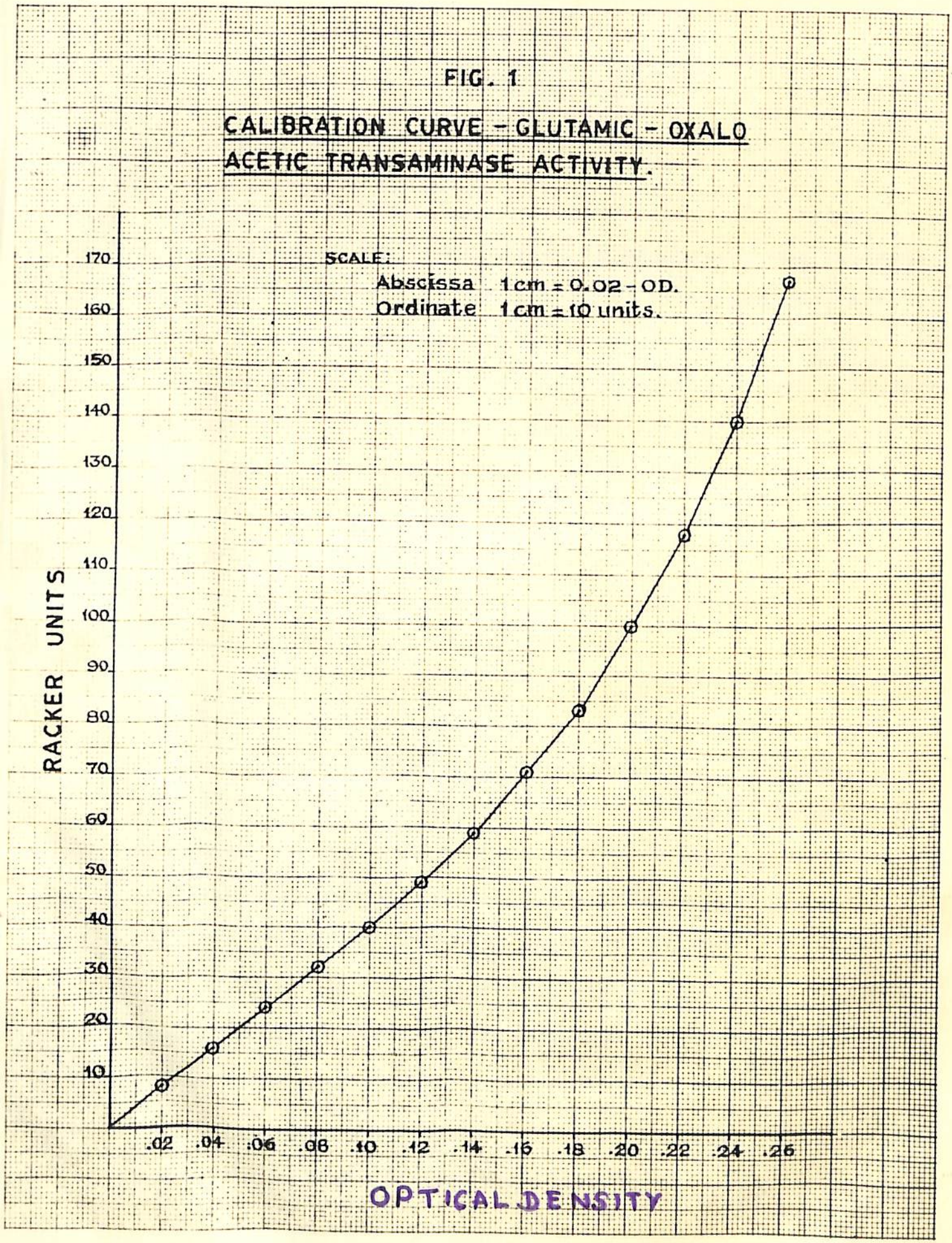
(2) Glutamic-pyruvic transaminase activity in liver - Method cited by Bergmeyer (1965)

Principle

Glutamate pyruvate transaminase catalyses the

FIG. 1

CALIBRATION CURVE - GLUTAMIC - OXALO ACETIC TRANSAMINASE ACTIVITY.



reaction:

L-glutamate + pyruvate $\rightleftharpoons$ L-alanine + α-oxoglutarate.

The activity of the transaminase is measured by the increase of pyruvate with time. After a fixed time, the pyruvate formed from L-alanine and α-oxoglutarate is determined colorimetrically by treating the 2,4-dinitrophenyl hydrazone with alkali. The residual α-oxoglutarate also froms a dinitrophenyl hydrazone but its absorption maximum in alkaline solution is different from that of the pyruvate hydrazone. Measurements are made between 500 and 550 mu instead of at wave length of maximum absorption of the pyruvate hydrazone.

Reagents

(i) Substrate buffer solution (0.1 M phosphate, pH 7.4, 0.2 M DL-alanine, 2×10^{-3} M α-oxoglutaric acid): Dissolved 1.50 g. of K_2HPO_4, 0.020 g. of KH_2PO_4, 0.030 g. of -oxoglutaric acid and 1.78 g. of DL-alanine in water. Adjusted the pH to 7.4 and made up the volume to 100 ml.

(ii) Ketone reagent (10^{-3} M 2,4-dinitrophenyl hydrazine): Dissolved 20 mg. of 2,4-dinitrophenyl hydrazine in 1 N hydrochloric acid and made up to 100 ml.

(iii) Sodium hydroxide (0.4 N): Dissolved 16 g. sodium hydroxide in water and made up to 1000 ml.

(iv) Sodium pyruvate (2×10^{-3}M): Dissolved 22 mg. of sodium pyruvate in water and made up to 100 ml.

Procedure

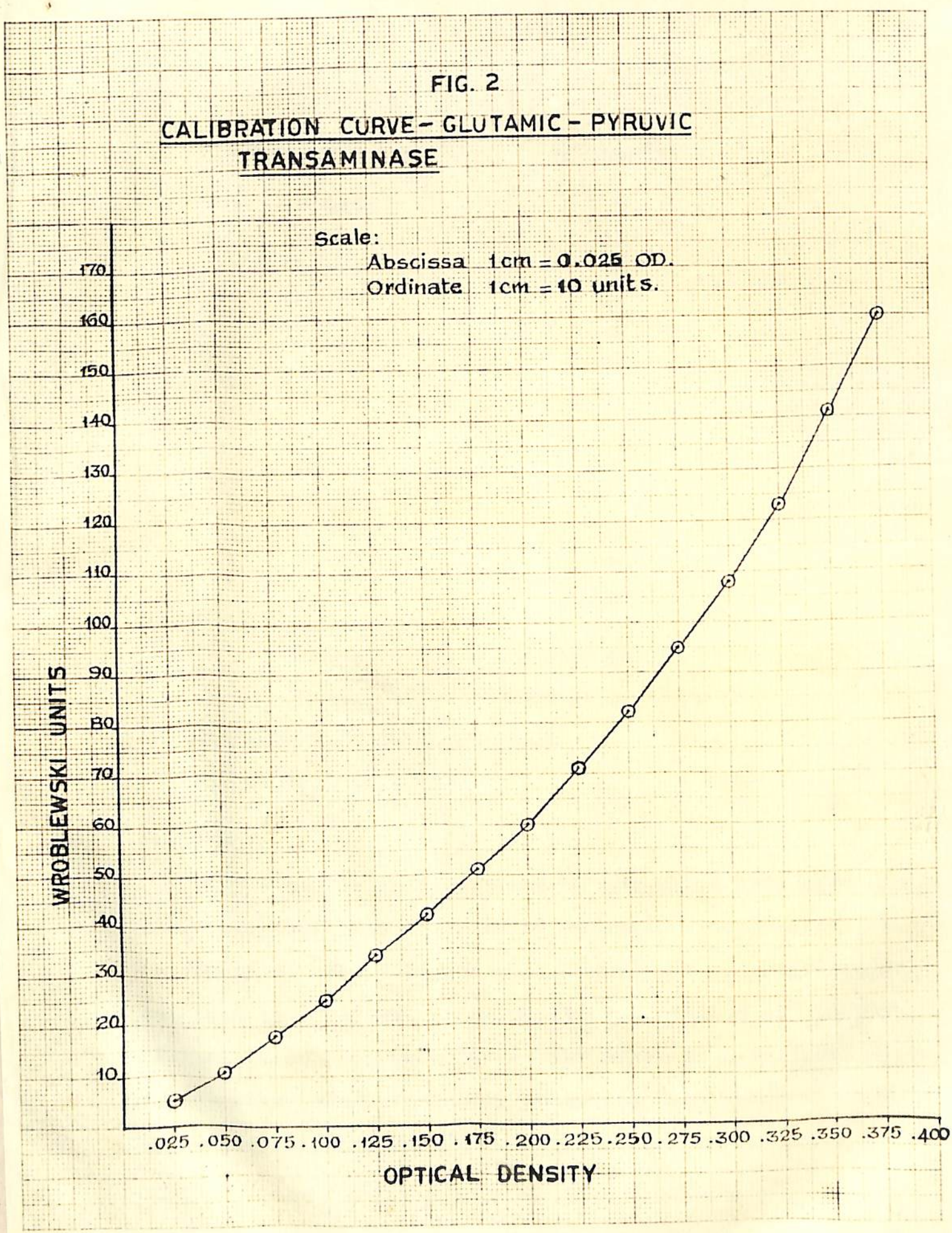
Experimental and blank tubes were prepared as follows:

Experimental	Blank
1. ml. of substrate buffer solution	1 ml. of substrate buffer solution
+	
0.2 ml. homogenate Mixed by inversion and incubated for exactly 30 minutes	Did not incubate
Added 1 ml. of ketone reagent	1 ml. of ketone reagent + 0.2 ml. of homogenate

Allowed to stand for 20 minutes at room temperature. Added 10 ml. of 0.4 N sodium hydroxide solution. Mixed and after 5 minutes the optical density of the experimental solution was measured against the blank in a Bausch and Laumb 'Spectronic 20' colorimeter at 546 mμ. A standard curve was prepared with values given in table (Bergmeyer, 1965) and unknown values were read from the curve (Fig. 2).

FIG. 2

CALIBRATION CURVE – GLUTAMIC – PYRUVIC TRANSAMINASE



Optical density	GPT units
0.025	5
0.050	11
0.075	18
0.100	25
0.125	34
0.150	42
0.175	51
0.200	60
0.225	71
0.250	82
0.275	95
0.300	108
0.325	123
0.350	141
0.375	160

IV. Estimation of liver glycogen

Method of Oser (1965)

Principle

The tissue is hydrolysed by potassium hydroxide and the glycogen is precipitated by ethanol. The precipitate is separated by centrifugation, hydrolysed by sulphuric acid, and then neutralised. A sulphuric acid medium of anthrone reagent, causes dehydration of the sugar to a furfural derivative which then presumably condenses with anthrone to form a blue coloured compound.

Reagents

(i) Potassium hydroxide (30%)

(ii) Ethanol (95%)

(iii) Ethanol (60%)

(iv) Sulphuric acid (95%)

(v) Anthrone solution (0.2% in 95% sulphuric acid): 0.2 g. of anthrone was disolved in 100 ml. of 95% sulphuric acid. Prepared fresh before use.

(vi) Standard glucose solution: A stock standard was prepared by dissolving exactly 1 g. of highest purity anhydrous glucose in saturated benzoid acid and diluting to 100 ml. with water. A working standard was prepared from this by diluting 1 ml. to 500 ml. with distilled water. 5 ml. of this working standard contains 100 µ g. of glucose.

(vii) Sulphuric acid (2 N)

(viii) Sodium hydroxide (1 N)

Procedure

Immediately after removal from the animal, approximately 1 g. of liver was dropped into a previously weighed test tube containing 3 ml. of 30% potassium hydroxide solution. The tube with contents was weighed again. The liver tissue was then digested by heating for 20 minutes in a boiling

water bath, agitating the solution occasionally to ensure thorough disintegration. Added 7 ml. of 95% alcohol to the tube, mixed by tapping and immersed it in a boiling water bath until boiling just began, care being taken to avoid losses by sudden foaming. Allowed the tubes to cool at room temperature for about 2 hours. Centrifuged, decanted and discarded the supernatant liquid. Drained and washed the precipitate twice with 5 ml. portions of 60% alcohol by centrifuging, decanting and draining as before. Expelled the last traces of alcohol by immersing the tubes in the boiling water bath. To each tube was then added 10 ml. of distilled water and stirred until a uniform suspension was obtained. Pipetted 5 ml. of the suspension into a clean test tube, and added 5 ml. of 2 N sulphuric acid to it. Heated the tube in a boiling water bath for 3 to 4 hours to hydrolyse the glycogen. Cooled. Added a drop of phenol red indicator and then neutralised cautiously with 1 N sodium hydroxide with constant stirring. Transferred the neutralised solution to a 100 ml. volumetric flask, diluted to volume with water and mixed.

Five ml. of aliquot, 5 ml. of glucose solution containing 100 µg. and 5 ml. of distilled water were taken in three separate tubes. While submerged in water, introduced 10 ml. of anthrone reagent into each tube with shaking. The tubes were then covered with glass marbles and heated for

10 minutes in a boiling water bath. Cooled the tubes. Compared the colour in a Bausch and Lomb 'Spectronic 20' colorimeter at 620 mμ after setting the instrument to zero with the blank.

Calculation:

$$\frac{\text{Reading of unknown} \times 100 \times \text{dilution factor} \times 100}{\text{Reading of standard} \times 1.11 \times \text{wt. of tissue in g.} \times 1000000} = \text{gram \%}$$

where 100 = concentration of standard in ug; 1.11 = conversion factor for glucose to glycogen and 100/1000000 = factor for expressing the value in g%.

Percentage composition of diets

Table 1

First series of experiments

Diets	Cowpea flour	Tur dhal flour	Casein	Corn starch	Sucrose	Hydrogenated vegetable oil	*Salt Mixture
A	51.0	-	-	22.0	17.0	5.0	5.0
B	-	49.0	-	24.0	17.0	5.0	5.0
C	-	-	10.0	63.0	17.0	5.0	5.0
D	51.0	-	-	22.0	17.0	5.0	5.0
E	-	49.0	-	24.0	17.0	5.0	5.0

* Steenbock and Nelson salt mixture No.40 + 0.03% $CuSO_4$, $5H_2O$
(Steenbock and Nelson, 1923; Pearson, Elvehjem and Hart, 1937).

Percentage composition of diets

Table 2

Second series of experiments

Diets	Cowpea flour	Tur dhal flour	Corn starch	Sucrose	Hydrogenated vegetable oil	*Salt Mixture
F@	51.0	-	22.0	17.0	5.0	5.0
G$	-	49.0	24.0	17.0	5.0	5.0
H@	51.0	-	22.0	17.0	5.0	5.0
I$	-	49.0	24.0	17.0	5.0	5.0

* Steenbock and Nelson salt mixture No.40 + 0.03% $CuSO_4$, $5H_2O$ (Steenbock and Nelson, 1923; Pearson, Elvehjem and Hart, 1937).

@ Diet F + 500 mg. of DL-Methionine + 140 mg. of L-Tryptophane
Diet H + 500 mg. of L-Methionine + 140 mg. of L-Tryptophane

$ Diet G + 510 mg. of L-Methionine + 180 mg. of L-Tryptophane
Diet I + 510 mg. of L-Methionine + 180 mg. of L-Tryptophane

L-Methionine and L-Tryptophane in the diets F, G, H and I were incorporated in such amounts as were essential to meet optimum requirements (Rose,1937; Block & Bolling,1956; Patwardhan and Ramachandran,1960 and Nonaka *et al.*,1961).

Percentage composition of diets

Table 3

Third series of experiments

Diets	Cowpea flour	Cowpea protein isolate	Tur dhal flour	Tur dhal protein isolate	Casein	Corn starch	Sucrose	Hydrogenated vegetable oil	*Salt Mixture
J	70.0	3.0	-	-	-	-	17.0	5.0	5.0
K	-	-	70.0	3.9	-	-	16.1	5.0	5.0
L	-	-	-	-	18.0	60.0	12.0	5.0	5.0

* Steenbock and Nelson salt mixture No.40 + 0.03% $CuSO_4$, $5H_2O$ (Steenbock and Nelson, 1923; Pearson, Elvehjem and Hart, 1937).

Percentage composition of diets

Table 4

Third series of experiments (Reproduction and lactation studies)

Diets	Cowpea flour	Cowpea protein isolate	Thur dhal flour	Thur dhal protein isolate	Casein	Corn starch	Sucrose	Hydrogenated vegetable oil	*Salt Maxture
M	70.0	3.0	-	-	-	-	17.0	5.0	5.0
N	-	-	70.0	3.9	-	-	16.1	5.0	5.0
O	-	-	-	-	18.0	60.0	12.0	5.0	5.0
P	70.0	3.0	-	-	-	-	17.0	5.0	5.0
Q	-	-	70.0	3.9	-	-	16.1	5.0	5.0

* Steenbock and Nelson salt mixture No.40 + 0.03% $CuSO_4$, £$5H_2O$ (Steenbock and Nelson, 1923; Pearson, Elvehjem and Hart, 1937).

RESULTS

RESULTS

The results of studies carried out during the course of the present investigation are presented under seperate heads.

FIRST SERIES OF EXPERIMENTS

Data on weekly weight gain of five groups of animals maintained on the different diets (Diets A, B, C, D and E) containing raw and autoclaved cowpea and tur dhal respectively, each at 10% protein level are presented in Tables 5 to 9. Total weight gain, total food consumed and protein efficiency values obtained in respect of these studies are detailed in Tables 10 to 14. The results of nitrogen balance studies are presented in tables 15 to 19 and data on digestibility coefficients of dry matter, Carbohydrate, protein and fat in Tables 20 to 24.

The results indicated are summarised in Tables 25 to 28 and statistically analysed in Tables 29 to 34. Data on red blood cell, haemoglobin and plasma protein concentrations are detailed in Tables 35 to 45 and summarised in Tables 46 and 47. Statistical analyses of these results are presented in Tables 48 to 50.

Tables 51 to 55 show data on glutamic-oxalo acetic

transaminase and glutamic-pyruvic transaminase levels in serum and liver samples obtained from rats sacrificed after 28 days on the respective diets. The results are summarised in Table 56 and statistically analysed in Tables 57 to 60.

The liver glycogen contents of animals fed the 5 test diets are set out in Table 61 and summarised in Table 62. Statistical analysis of the results is presented in Table 63.

Data on liver fat and liver protein concentrations of rats fed the test diets are set out in Tables 64 to 68, summarised and statistically analysed in Tables 69 to 71.

Weights of liver, spleen, kidney and heart of animals fed the different diets for a period of 28 days are presented in Tables 72 to 76. These results are summarised in Table 77 and statistically analysed in Tables 78 to 81. Values for caecal weights of animals fed the respective diets for a period of 28 days are given in Tables 82 to 86. The results are summarised in Table 87 and statistically analysed in Tables 88 and 89. Data on weight of pancreas of the animals fed the respective diets are given in Tables 90 to 94. The summarised data are given in Table 95. Table 96 shows the results of statistical analyses.

In figures 3 and 5 to 9 are represented results on growth rate, weight gain, protein efficiency, per cent nitrogen retention, liver protein and liver fat contents.

SECOND SERIES OF EXPERIMENTS

Data showing the weekly weight gain of 4 groups of animals maintained on different diets (Diets F, G, H and I) are presented in Tables 97 to 100 and summarised in Table 113. Total weight gain, total food consumed and the protein efficiency values obtained during the course of the study are presented in Tables 101 to 104 and summarised in Table 114. Data on nitrogen balance, digestibility coefficients of dry matter, carbohydrate, protein and fat are presented in Tables 105 to 108 and 109 to 112 respectively, summarised in Tables 115 and 116 respectively. The above results are statistically analysed in Tables 117 to 122.

Data on red blood cell, haemoglobin and plasma protein concentrations are given in Tables 123 to 131, summarised in Tables 132 and 133 and statistically analysed in Tables 134 to 136.

Data on liver and serum enzymes and liver glycogen contents are set out in Tables 137 to 141, summarised in Tables 142 and 143 respectively and statistically analysed in Tables 144 to 148.

Values for liver fat and liver protein concentrations of rats fed the test diets are given in Tables 149 to 152, summarised in Table 153 and statistically analysed in Tables 154 and 155.

Weights of liver, spleen kidney and heart of animals fed the different diets are given in Tables 156 to 159. These values are summarised in Table 160 and statistically analysed in Tables 161 to 164.

Data on ceacal weights of animals scarificed at the end of the experimental period of 28 days are set out in Tables 165 to 168, summarised in Table 169 and statistically analysed in Tables 170 and 171. Data on weight of pancreas of animals fed the test diets are given in Tables 172 to 175, summarised in Table 176 and statistical analysis given in Table 177.

Growth rate, body weight gain, protein efficiency values, per cent nitrogen retention, liver protein and liver fat contents are graphically represented in Figures 4 to 9 respectively.

THIRD SERIES OF EXPERIMENTS

Data showing the weekly weight gain of animals maintained on different diets (Diets J, K and L) are presented in Tables 178 to 180. Data on red blood cell and haemoglobin concentrations are given in Tables 181 to 186. Data presented in these Tables are summarised in Table 187 and statistically analysed in Tables 188 to 190. Tables 191 to 193 present the total weight gain, total food consumption and protein efficiency values recorded in animals maintained on the test diets. Data detailed in Tables 191 to 193 are summarised in Table 194 and statistically analysed in Table 195.

Data obtained on the reproduction and lactation performances of animals maintained on the different test diets (Diets M, N, O, P and Q) are furnished in Tables 196 to 200 and aressummarised in Table 201.

Statistical analyses of the results

Test diets were given to sufficient number of animals so that the results could be analysed by following the method for the analysis of one way classification, the numbers of animals fed each diet and the environmental conditions of the experimental regimes being the essentially the same. The differences in effectiveness of the diets were compared

by computing critical difference where the expression for critical difference is $t_0 \times \sqrt{\frac{2}{r} \times E}$. In this expression t_0 = the critical value of Students 't' at the appropriate level of significance, r = the number of replication of a diet and E is the mean error sum of squares in the corresponding analysis of variance table.

To compare diets between two experiments, for instance, raw diet versus heated diet, the significant difference between variance was first determined with the help of the respective Mean Error sum of squares. In cases where there were no significant differences between variances, Student's 't' was used to compare one diet in one series of experiment with any diet in another series of experiment. Where the variances were found to be significantly different, Cochran's 't' was employed to test significant differences between diets belonging to two groups(Snedecor, 1956).

FIRST SERIES OF EXPERIMENTS

Table 5

Body weight in g. of animals receiving diets containing Cowpea and Tur dhal, raw and autoclaved, at 10% protein level on nitrogen basis

Diet A

Rat No.	Weeks				
	0	1	2	3	4
1	50.0	50.0	51.0	52.0	54.0
2	43.0	41.0	41.0	40.0	40.0
3	58.0	58.0	59.0	58.0	56.0
4	58.0	55.0	52.0	55.0	55.0
5	50.0	50.0	49.0	51.0	54.0
6	48.0	50.0	50.0	52.0	52.0
7	52.0	50.0	52.0	55.0	56.0
8	57.0	54.0	56.0	57.0	60.0
9	60.0	58.0	58.0	60.0	65.0
10	58.0	56.0	59.0	60.0	62.0
Average $\bar{c}$	53.4	52.2	52.7	54.0	55.4
Standard Error	± 1.77	± 1.62	± 1.76	± 1.86	± 2.14

Table 6

Diet B

Rat No.	0	1	2	3	4
1	53.0	50.0	50.0	49.0	49.0
2	55.0	54.0	54.0	50.0	51.0
3	44.0	41.0	41.0	40.0	40.0
4	54.0	52.0	50.0	49.0	49.0
5	50.0	52.0	55.0	59.0	59.0
6	55.0	57.0	58.0	58.0	59.0
7	60.0	58.0	60.0	61.0	64.0
8	57.0	52.0	55.0	54.0	54.0
9	54.0	52.0	54.0	56.0	60.0
10	50.0	52.0	52.0	53.0	55.0
Average $\bar{c}$	53.2	52.0	52.9	52.9	54.0
Standard Error	$\pm$ 1.35	$\pm$ 1.45	$\pm$ 1.66	$\pm$ 2.52	$\pm$ 2.22

Table 7

Diet C

Rat No.	Weeks 0	1	2	3	4
1	40.0	48.0	55.0	57.0	67.0
2	54.0	59.0	65.0	71.0	80.0
3	63.0	69.0	78.0	87.0	93.0
4	60.0	67.0	79.0	88.0	98.0
5	57.0	75.0	97.0	103.0	114.0
6	54.0	67.0	80.0	88.0	97.0
7	56.0	72.0	87.0	93.0	97.0
8	50.0	64.0	84.0	92.0	99.0
9	49.0	65.0	85.0	99.0	118.0
10	50.0	66.0	92.0	99.0	109.0
Average $\bar{c}$	53.3	65.2	80.2	87.7	97.2
Standard Errer	$\pm$ 2.05	$\pm$ 2.32	$\pm$ 3.91	$\pm$ 4.42	$\pm$ 4.81

Table 8

Diet D

Rat No.	Weeks				
	0	1	2	3	4
1	58.0	63.0	69.0	73.0	83.0
2	54.0	63.0	74.0	80.0	87.0
3	54.0	60.0	71.0	86.0	92.0
4	65.0	71.0	86.0	97.0	102.0
5	55.0	61.0	67.0	79.0	89.0
6	57.0	64.0	65.0	70.0	78.0
7	43.0	44.0	46.0	56.0	62.0
8	43.0	45.0	47.0	50.0	55.0
9	48.0	47.0	48.0	57.0	63.0
10	50.0	50.0	55.0	64.0	68.0
Average $\bar{c}$	52.7	56.8	62.8	71.2	77.9
Standard Error	$\pm$ 2.17	$\pm$ 2.73	$\pm$ 4.22	$\pm$ 5.72	$\pm$ 4.82

Table 9

Diet E

Rat No.	Weeks				
	0	1	2	3	4
1	51.0	55.0	62.0	67.0	76.0
2	56.0	55.0	60.0	66.0	75.0
3	56.0	60.0	70.0	75.0	88.0
4	58.0	64.0	75.0	81.0	95.0
5	55.0	59.0	66.0	70.0	83.0
6	58.0	61.0	67.0	76.0	83.0
7	54.0	59.0	65.0	72.0	77.0
8.	56.0	61.0	67.0	70.0	80.0
9	55.0	60.0	68.0	73.0	82.0
10	55.0	58.0	67.0	77.0	83.0
Average $\bar{c}$	55.2	59.2	66.7	72.7	82.2
Standard Error	± 1.69	± 0.87	± 1.21	± 1.47	± 1.89

Table 10

Weight gain, feed consumption, protein efficiency values of animals fed diets A, B, C, D and E at 10% protein level on nitrogen basis

Diet A

Rat No.	Initial weight (g)	Final weight (g.)	Weight gain (g.)	Food intake (g.)	Protein intake (g.)	Protein efficiency value
1	50.0	54.0	4.0	116.0	11.6	0.34
2	43.0	40.0	-3.0	118.0	11.8	-0.25
3	58.0	56.0	-2.0	106.4	10.6	-0.19
4	58.0	55.0	-3.0	135.9	13.6	-0.22
5	50.0	54.0	4.0	137.7	13.8	0.29
6	48.0	52.0	4.0	145.4	14.5	0.28
7	52.0	56.0	4.0	144.4	14.4	0.28
8	57.0	60.0	3.0	148.7	14.9	0.20
9	60.0	65.0	5.0	136.8	13.7	0.36
10	58.0	62.0	4.0	144.4	14.4	0.28
Average $\bar{c}$	53.4	55.4	2.0	133.3	13.3	0.14
Standard Errer	$\pm$ 1.77	$\pm$ 2.14	$\pm$ 1.03	$\pm$ 4.50	$\pm$ 0.46	$\pm$ 0.08

Table 11

Diet B

Rat No.	Initial weight (g.)	Final weight 1(g.)	Weight gain (g.)	Food intake (g.)	Protein intake (g.)	Protein efficiency value
1	53.0	49.0	-4.0	121.0	12.1	-0.33
2	55.0	51.0	-4.0	114.0	11.4	-0.35
3	44.0	40.0	-4.0	108.0	10.8	-037
4	54.0	49.0	-5.0	112.0	11.2	-0.45
5	50.0	59.0	9.0	148.2	14.8	0.67
6	55.0	59.0	4.0	133.9	13.4	0.30
7	60.0	64.0	4.0	103.5	10.4	0.38
8	57.0	54.0	-3.0	131.0	13.1	-0.23
9	54.0	60.0	6.0	136.8	13.7	0.44
10	50.0	55.0	5.0	116.8	11.7	0.43
Average $\bar{c}$	53.2	54.0	0.8	122.5	12.3	0.05
Standard Error	$\pm$ 1.35	$\pm$ 2.22	$\pm$ 1.46	$\pm$ 4.54	$\pm$ 0.45	$\pm$ 0.14

Table 12

Diet C

Rat No.	Initial weight (g.)	Final weight (g.)	Weight gain (g.)	Food intake (g.)	Protein intake (g.)	Protein efficiency value
1	40.0	67.0	27.0	141.0	14.1	1.91
2	54.0	80.0	26.0	172.0	17.2	1.51
3	63.0	93.0	30.0	150.0	15.0	2.00
4	60.0	98.0	38.0	125.0	12.5	3.04
5	57.0	114.0	57.0	205.0	20.5	2.78
6	54.0	97.0	43.0	190.0	19.0	2.26
7	56.0	97.0	41.0	182.4	18.2	2.25
8	50.0	99.0	49.0	184.3	18.4	2.66
9	49.0	118.0	69.0	203.3	20.3	3.39
10	50.0	109.0	59.0	204.2	20.4	2.89
Average $\bar{c}$	53.3	97.2	43.9	175.7	17.6	2.47
Standard Error	$\pm$ 2.05	$\pm$ 4.81	$\pm$ 4.59	$\pm$ 28.51	$\pm$ 0.89	$\pm$ 0.18

Table 13

Diet D

Rat No.	Initial weight (g.)	Final weight (g.)	Weight gain (g.)	Food intake (g.)	Protein intake (g.)	Protein efficiency value
1	58.0	83.0	25.0	170.1	17.0	1.47
2	54.0	87.0	33.0	179.6	17.9	1.84
3	54.0	92.0	38.0	193.8	19.4	1.96
4	65.0	102.0	37.0	239.4	23.9	1.55
5	55.0	89.0	34.0	175.7	17.6	1.93
6	57.0	78.0	21.0	171.0	17.1	1.23
7	43.0	62.0	19.0	177.6	17.8	1.07
8	43.0	55.0	12.0	146.3	14.6	0.82
9	48.0	63.0	15.0	177.6	17.8	0.84
10	50.0	68.0	18.0	194.7	19.5	0.92
Average $\bar{c}$	52.7	77.9	25.2	182.6	18.3	1.40
Standard Error	$\pm$ 2.17	$\pm$ 4.82	$\pm$ 3.03	$\pm$ 7.61	$\pm$ 0.75	$\pm$ 0.14

Table 14

Diet E

Rat No.	Initial weight (g.)	Final weight (g.)	Weight gain (g.)	Food intake (g.)	Protein intake (g.)	Protein efficiency value
1	51.0	76.0	25.0	159.6	15.9	1.57
2	56.0	75.0	19.0	134.9	13.5	1.41
3	56.0	88.0	32.0	175.8	17.6	1.82
4	58.0	95.0	37.0	176.7	17.7	2.09
5	55.0	83.0	28.0	138.7	13.9	2.01
6	58.0	83.0	25.0	151.1	15.1	1.65
7	54.0	77.0	23.0	182.0	18.2	1.30
8	56.0	80.0	24.0	176.6	17.7	1.35
9	55.0	82.0	27.0	168.4	16.8	1.61
10	55.0	83.0	28.0	181.6	18.2	1.53
Average $\bar{c}$	55.2	82.2	26.8	164.5	16.5	1.63
Standard Error	$\pm$ 1.69	$\pm$ 1.89	$\pm$ 1.57	$\pm$ 5.56	$\pm$ 0.56	$\pm$ 0.08

Table 15

Nitrogen balance studies

Diet A

Rat No.	Weight in g.	Body surface cm^2	Nitrogen intake (4 days) mg.	N. Excretion (4 days)			Nitrogen balance mg./day	Nitrogen balance mg./100 cm^2 body surface	Percent N. retention
				Urinary mg.	Faecal mg.	Total mg.			
1	54.0	137.3	256.0	140.0	87.5	227.5	7.1	5.2	11.1
2	40.0	113.7	216.0	161.0	71.8	232.8	-4.2	-3.7	-7.8
3	56.0	140.4	224.0	203.0	71.8	274.8	-12.7	-9.0	-22.7
4	55.0	138.9	240.0	147.0	110.0	257.0	-4.2	-3.0	-7.1
5	54.0	137.3	353.6	290.6	78.4	369.0	-3.8	-2.7	-4.4
6	52.0	134.3	320.0	180.5	84.0	264.5	13.9	10.3	17.3
7	56.0	140.4	248.0	164.5	51.8	216.3	7.9	5.6	12.8
8	60.0	146.3	340.0	248.0	62.3	310.3	7.4	5.1	8.7
9	65.0	153.5	320.0	232.0	53.9	285.9	8.5	5.5	10.7
10	62.0	149.2	336.0	224.0	94.8	318.8	4.3	2.9	5.1
Average $\bar{c}$	55.4	139.2	285.4	199.1	76.6	275.7	2.4	1.6	2.4
Standard Error	± 2.14	± 4.42	± 16.83	± 15.79	± 5.78	± 8.11	± 2.59	± 1.88	± 3.93

Table 16

Diet B

Rat No.	Weight in g.	Body surface cm^2	Nitrogen intake (4 days) mg.	N. Excretion (4 days) Urinary mg.	Faecal mg.	Total mg.	Nitrogen balance mg./day	Nitrogen balance mg./100 cm^2 body surface	Percent N. retention
1	49.0	129.5	384.0	304.5	91.5	396.0	-3.0	-2.3	-3.1
2	51.0	132.6	360.0	282.0	89.4	371.4	-2.8	-2.1	-3.2
3	40.0	114.7	376.0	309.0	101.3	410.3	-8.6	-7.5	-9.1
4	49.0	129.5	328.0	227.8	92.7	320.5	1.9	1.5	2.3
5	59.0	144.8	400.0	244.0	88.4	332.4	16.9	11.7	16.9
6	59.0	144.8	296.0	204.0	65.4	269.4	6.6	4.6	9.0
7	64.0	152.1	296.0	220.6	58.2	278.8	4.3	2.8	5.8
8	54.0	137.3	248.0	170.4	75.6	246.0	0.5	0.4	0.8
9	60.0	146.3	280.0	180.9	84.5	265.4	3.6	2.5	5.2
10	55.0	141.9	368.0	253.0	127.0	380.0	-3.0	-2.1	-3.3
Average $\bar{c}$	54.0	137.0	333.6	239.6	87.4	327.0	1.6	1.4	2.1
Standard Error	± 2.22	± 3.44	± 16.22	± 15.29	± 6.05	± 19.01	± 2.20	± 1.58	± 2.36

Table 17

Diet C

Rat No.	Weight in g.	Body surface cm^2	Nitrogen intake (4 days) mg.	N. Excretion (4 days)			Nitrogen balance mg./day	Nitrogen balance mg./100 cm^2 body surface	Percent N. retention
				Urinary mg.	Faecal mg.	Total mg.			
1	67.0	159.3	352.0	65.4	38.8	104.2	61.9	39.6	70.4
2	80.0	173.9	368.0	36.6	17.8	54.4	78.4	45.1	85.2
3	93.0	190.3	416.0	82.1	17.0	69.1	86.7	45.6	83.4
4	98.0	196.3	504.0	82.4	34.5	116.9	96.7	49.3	76.8
5	114.0	215.0	416.0	38.0	26.1	64.1	87.9	40.9	84.6
6	97.0	195.1	528.0	41.4	19.3	60.7	116.8	59.9	88.5
7	97.0	195.1	352.0	51.4	21.1	72.5	69.9	35.8	80.1
8	99.0	197.5	208.0	32.0	18.3	50.3	39.4	19.9	75.8
9	118.0	219.5	304.0	24.0	33.0	57.0	61.7	28.1	81.2
10	109.0	207.2	288.0	62.2	20.1	82.3	51.4	24.8	71.4
Average $\bar{c}$	97.2	194.6	373.6	48.5	24.6	73.1	75.1	38.9	79.7
Standard Error	$\pm$ 4.81	$\pm$ 7.20	$\pm$ 30.73	$\pm$ 5.59	$\pm$ 2.53	$\pm$ 6.95	$\pm$ 7.25	$\pm$ 3.83	$\pm$ 1.91

Table 18

Diet D

Rat No.	Weight in g.	Body surface cm^2	Nitrogen intake (4 days) mg.	N. Excretion (4 days) Urinary mg.	Faecal mg.	Total mg.	Nitrogen balance mg./day	Nitrogen balance $mg./100\ cm^2$ body surface	Percent N. retention
1	83.0	177.7	494.4	150.5	96.6	247.1	61.8	34.8	50.0
2	87.0	182.8	461.4	113.9	50.3	164.2	74.3	40.6	64.4
3	92.0	189.0	494.4	125.4	67.1	192.1	75.6	40.0	61.1
4	102.0	201.1	494.4	154.5	75.4	229.9	66.1	32.9	53.5
5	89.0	185.3	510.8	108.8	54.0	168.8	85.5	46.1	67.0
6	78.0	171.2	477.9	168.7	107.5	276.2	50.4	29.4	42.2
7	62.0	149.1	576.8	204.4	116.9	321.3	63.9	42.8	44.3
8	55.0	138.9	461.4	129.0	78.8	207.8	63.4	45.6	54.9
9	63.0	150.5	576.8	135.0	140.5	275.5	75.3	50.0	52.2
10	68.0	157.7	494.4	187.0	60.4	247.4	61.7	39.1	49.9
Average $\bar{c}$	77.9	170.3	504.3	147.7	84.7	233.0	67.8	40.1	53.9
Standard Error	$\pm$ 4.82	$\pm$ 6.43	$\pm$ 13.05	$\pm$ 9.95	$\pm$ 9.40	$\pm$ 16.01	$\pm$ 3.14	$\pm$ 2.02	$\pm$ 2.58

Table 19

Diet E

Rat No.	Weight in g.	Body surface cm^2	Nitrogen intake (4 days) mg.	N. Excretion (4 days)			Nitrogen balance mg./day	Nitrogen balance $mg_2/100$ cm^2 body surface	Percent N. retention
				Urinary mg.	Faecal mg.	Total mg.			
1	76.0	168.6	480.0	266.0	23.8	289.8	47.5	28.2	39.6
2	75.0	176.2	448.0	186.6	37.9	224.5	55.9	33.4	49.9
3	88.0	184.1	528.0	152.4	59.4	211.8	79.0	42.9	59.9
4	95.0	192.7	640.0	108.8	99.5	208.3	107.9	55.9	67.4
5	83.0	177.7	480.0	189.3	77.6	266.9	53.3	30.0	44.4
6	83.0	177.7	528.0	141.3	87.9	229.2	74.7	42.0	56.6
7	77.0	109.9	533.0	164.5	54.8	219.3	78.4	46.1	58.8
8	80.0	173.8	436.0	128.4	39.9	168.3	66.9	38.5	61.4
9	82.0	176.4	468.0	254.9	64.5	319.4	37.2	21.1	31.7
10	83.0	177.7	546.0	151.5	57.0	208.5	84.4	47.5	61.8
Average $\bar{c}$	82.2	171.5	508.7	174.4	60.2	234.6	68.5	38.6	53.1
Standard Error	$\pm$ 1.89	$\pm$ 7.13	$\pm$ 18.92	$\pm$ 16.39	$\pm$ 7.38	$\pm$ 13.94	$\pm$ 6.55	$\pm$ 3.30	$\pm$ 3.59

Table 20

Digestibility coefficients of dry matter, protein, carbohydrate and fat in diets A, B, C, D and E.

Diet A

Rat No.	Drymatter	Protein	Carbohydrate	Fat
1	87.5	65.8	89.1	90.3
2	90.4	66.7	91.2	91.4
3	90.0	67.9	93.8	89.3
4	90.0	54.2	87.4	87.7
5	86.3	77.8	89.4	93.3
6	88.5	73.7	89.5	92.8
7	89.6	79.1	87.6	93.1
8	85.9	81.7	87.4	89.9
9	87.5	93.1	90.5	90.0
10	89.5	71.8	91.5	90.5
Average $\bar{c}$	88.5	72.2	89.7	90.8
Standard Error	± 0.51	± 2.79	± 0.65	± 0.57

Table 21

Diet B

Rat No.	Drymatter	Protein	Carbohydrate	Fat
1	93.7	75.9	89.4	90.1
2	89.3	75.2	87.5	87.1
3	91.4	73.0	85.4	89.9
4	86.3	71.7	84.5	90.4
5	76.1	77.9	94.5	85.6
6	74.6	77.9	92.3	86.8
7	82.7	80.3	91.4	87.1
8	78.7	69.5	89.5	90.4
9	88.0	69.8	88.6	90.3
10	89.5	65.5	87.9	89.9
Average $\bar{c}$	85.0	73.7	89.1	88.8
Standard Error	$\pm$ 2.23	$\pm$ 1.95	$\pm$ 0.97	$\pm$ 0.51

Table 22

Diet C

Rat No.	Drymatter	Protein	Carbohydrate	Fat
1	97.3	85.3	95.4	93.5
2	98.8	93.3	94.6	96.7
3	96.8	90.2	96.5	88.8
4	91.5	90.3	94.8	90.4
5	97.3	88.7	89.8	91.3
6	93.3	89.5	90.4	94.3
7	94.5	99.0	95.4	92.0
8	96.8	99.4	96.8	90.8
9	95.3	96.5	94.3	91.3
10	89.9	96.5	92.4	89.4
Average $\bar{c}$	95.1	92.9	94.0	91.8
Standard Error	$\pm$ 0.89	$\pm$ 1.52	$\pm$ 0.76	$\pm$ 1.61

Table 23

Diet D

Rat No.	Drymatter	Protein	Carbohydrate	Fat
1	96.6	80.5	90.4	91.3
2	95.3	89.1	95.4	90.8
3	90.6	86.4	91.5	88.9
4	96.0	84.7	89.5	90.0
5	92.4	89.4	90.5	91.3
6	94.1	77.5	84.5	89.5
7	95.7	79.7	88.6	86.3
8	95.0	82.9	83.6	85.4
9	96.2	75.6	95.4	92.5
10	96.6	87.8	92.8	95.1
Average $\bar{c}$	94.8	83.4	91.2	90.1
Standard Error	$\pm$ 0.63	$\pm$ 1.55	$\pm$ 1.14	$\pm$ 0.90

- 101 -

Table 24

Diet E

Rat No.	Drymatter	Protein	Carbohydrate	Fat
1	90.6	95.0	91.4	88.9
2	90.7	91.5	92.3	91.3
3	90.3	88.7	89.4	90.4
4	92.2	84.4	91.3	93.3
5	91.3	83.8	94.4	95.9
6	91.3	83.3	93.1	94.6
7	90.5	87.8	93.4	93.5
8	94.2	95.4	90.3	91.8
9	90.4	91.6	91.2	94.3
10	89.6	92.5	88.4	89.8
Average $\bar{c}$	91.1	89.4	91.5	92.4
Standard Error	± 0.53	± 1.42	± 0.58	± 2.18

Table 25

Summarised data* on body weight recorded in respect of groups of rats maintained on diets A, B, C, D and E

(Vide Tables 5 to 9)

Diets	No. of animals	Food intake	Weeks				
			0	1	2	3	4
A	10	133.4± 4.50	53.4± 1.77	52.2± 1.62	52.7± 1.76	54.0± 1.86	55.4± 2.14
B	10	122.5± 4.54	53.2± 1.35	52.0± 1.45	52.9± 1.66	52.9± 2.52	54.0± 2.22
C	10	175.7± 8.95	53.3± 2.05	65.2± 2.32	80.2± 3.91	87.7± 4.42	97.2± 4.81
D	10	182.6± 7.61	52.7± 2.17	56.8± 2.73	62.8± 4.22	71.2± 5.72	77.9± 4.82
E	10	164.5± 5.56	55.2± 1.69	59.2± 0.87	66.7± 1.21	72.7± 1.47	82.2± 1.89

* Mean values (10 animals/group) with standard error.

Table 26

Summarised data* on body weight gain, food consumption and protein efficiency values recorded in respect of groups of rats maintained on diets A, B, C, D and E (Vide Tables 10 to 14)

Diets	No. of animals	Initial body weight(g.)	Final body weight(g.)	Weight gain (g.)	Food intake (g.)	Protein intake (g.)	Protein efficiency value
A	10	53.4± 1.77	55.4± 2.14	2.00± 1.03	133.4± 4.50	13.3± 0.46	0.14± 0.08
B	10	53.2± 1.35	54.0± 2.22	0.80± 1.46	122.5± 4.54	12.3± 0.45	0.05± 0.14
C	10	53.3± 2.05	97.2± 4.81	43.90± 4.59	175.7± 8.95	17.6± 0.89	2.47± 0.18
D	10	52.7± 2.17	77.9± 4.82	25.20± 3.03	182.6± 7.61	18.3± 0.75	1.40± 0.14
E	10	55.2± 1.69	82.2± 1.89	26.80± 1.57	164.5± 5.56	16.5± 0.56	1.63± 0.08

* Mean values (10 animals/group) with standard error.

Table 27

Summarised data* on nitrogen retention recorded in respect of groups of rats maintained on diets A, B, C, D and E
(Vide Tables 15 to 19)

Diets	Weight in(g.)	Body surface cm^2	Nitrogen intake (4 days mg.)	N. Excretion (4 days)			Nitrogen balance mg./day	Nitrogen balance mg./100 cm^2 body surface	Percent N. retention
				Urinary mg.	Faecal mg.	Total mg.			
A	55.4± 2.14	139.2± 4.42	285.4± 16.83	199.1± 15.79	76.6± 5.78	275.7± 8.11	2.4± 2.59	1.6± 1.88	2.4± 3.93
B	54.0± 2.22	137.0± 3.44	333.6± 16.22	239.6± 15.29	87.4± 6.05	327.0± 19.01	1.6± 2.20	1.4± 1.58	2.1± 2.36
C	97.2± 4.81	194.6± 7.20	373.6± 30.73	48.5± 5.59	24.6± 2.53	73.1± 6.95	75.1± 7.25	38.9± 3.83	79.7± 1.91
D	77.9± 4.82	170.3± 6.43	504.3± 13.05	147.7± 9.95	84.7± 9.40	233.0± 16.01	67.8± 3.14	40.1± 2.02	53.9± 2.58
E	82.2± 1.89	171.5± 7.13	508.7± 18.92	174.4± 16.39	60.2± 7.38	234.6± 13.94	68.5± 6.55	38.6± 3.30	53.1± 3.59

*Mean values (10 animals/group) with standard error.

Table 28

Summarised data* on digestibility coefficients recorded in respect of groups of rats fed diets A, B, C, D & E. (Vide tables 20 to 24)

Diets	Dry matter	Protein	Carbohydrate	Fat
A	88.5± 0.51	72.2± 2.79	89.7± 0.65	90.8± 0.57
B	85.0± 2.23	73.7± 1.95	89.1± 0.97	88.8± 0.51
C	95.1± 0.89	92.9± 1.52	94.0± 0.76	91.8± 1.61
D	94.8± 6.3	83.4± 1.55	91.2± 1.14	90.1± 0.90
E	91.1± 0.53	89.4± 1.42	91.5± 0.58	92.4± 2.18

*Mean values (10 animals/group) with standard error.

Table 29

Analysis of variance-Body weight gain in g.

Source	df.	SS.	MSS.	F.
Between diets	4	13367.92	3341.98	45.64*
Error	45	3295.70	73.24	
Total	49	16663.62		

* Significant at 1% level.

Critical difference

8.42 at 5% level

11.09 at 1% level

Mean values:

A = 2.00 B = 0.80 C = 43.9 D = 25.2 E = 26.8

Table 30

Analysis of variance-Protein efficiency values

Source	df.	SS.	MSS.	F.
Between diets	4	42.56	10.64	62.59**
Error	45	7.71	0.17	
Total	49	50.27		

** Significant at 1% level.

Critical difference:

0.32 at 5% level

0.42 at 1% level

Mean values:

Diets	A	B	C	D	E
	0.14	0.05	2.47	1.40	1.63

Table 31

Analysis of variance-% Nitrogen retention

Source	df.	SS.	MSS.	F.
Between diets	4	47812.30	11953.07	135.09**
Error	45	3981.57	88.48	
Total	49	51793.87		

** Significant at 1% level.

Critical difference: 7.24 at 5% level

9.53 at 1% level

Mean values: A = 2.4 B = 2.1 C = 79.7 D = 53.9 E = 53.1

Table 32

Analysis of variance-Digestibility coefficient of carbohydrate

Source	df.	SS.	MSS.	F.
Between diets	4	145.67	36.42	5.06**
Error	45	323.53	7.19	
Total	49	469.20		

** Significant at 1% level.

Critical difference:

2.34 at 5% level

3.09 at 1% level

Mean values

A = 89.7 B = 89.1 C = 94.0 D = 91.2 E = 91.5

Table 33

Analysis of variance-Digestibility coefficient protein

Source	df.	SS.	MSS.	F.
Between diets	4	3198.08	799.52	22.74**
Error	45	1581.94	35.15	
Total	49	4780.02		

** Significant at 1% level.

Critical difference:

5.01 at 5% level

6.59 at 1% level

Mean values

A = 72.2 B = 73.7 C = 92.9 D=83.4 E = 89.4

Table 34

Analysis of variance-Digestibility coefficient fat

Source	df.	SS.	MSS.	F.
Between diets	4	82.278	20.569	3.98**
Error	45	232.662	5.17	
Total	49	314.940		

** Significant at 1% level.

Critical difference:

3.53 at 5% level

4.65 at 1% level

Mean values

A = 90.8 B = 88.8 C = 91.8 D = 90.1 E = 91.4

Table 35

Red blood cell concentration of animals receiving diets A, B, C, D & E.

Diet A

(R.B.C.in millions/mm^3)

Rat No.	Weeks				
	0	1	2	3	4
1	7.01	7.04	7.17	7.61	7.70
2	6.36	6.48	6.55	6.58	6.95
3	6.19	6.08	7.01	7.94	7.79
4	7.12	7.32	7.51	7.86	7.81
5	6.54	6.58	6.61	7.05	8.16
6	7.04	7.21	7.64	8.01	8.34
7	6.64	6.65	6.82	7.51	7.94
8	6.32	6.45	6.68	6.82	7.09
9	7.04	7.12	7.54	8.01	8.25
10	6.68	7.01	7.41	7.52	7.65
Average $\bar{c}$	6.69±	6.79±	7.09±	7.49±	7.77±
Standard error	0.10	0.13	0.13	0.16	0.14

Table 36

Diet B

(R.B.C.in millions/mm^3)

Rat No.	Weeks				
	0	1	2	3	4
1	6.52	6.57	6.93	7.06	7.46
2	6.12	6.21	7.02	7.53	7.91
3	6.41	6.59	7.02	7.89	7.86
4	6.84	6.91	7.18	7.44	7.48
5	6.82	7.04	7.21	7.56	7.84
6	6.54	7.02	7.42	7.64	8.12
7	7.12	7.46	7.56	7.82	7.88
8	7.56	7.67	7.74	7.81	7.94
9	7.21	7.30	7.42	7.58	8.19
10	7.41	7.80	7.84	7.86	7.88
Average $\bar{c}$	6.85±	7.06±	7.33±	7.62±	7.86±
Standard Error	0.14	0.16	0.09	0.08	0.23

Table 37

Diet C

(R.B.C.in millions/mm^3)

Rat No.	Weeks				
	0	1	2	3	4
1	6.01	6.19	6.46	7.03	7.08
2	7.21	7.26	7.54	7.85	8.13
3	7.14	7.20	7.46	7.62	7.69
4	7.43	7.52	7.53	7.64	7.82
5	7.54	7.59	7.64	7.83	7.91
6	7.58	7.88	8.02	8.19	8.28
7	7.64	7.89	7.88	8.12	8.34
8	7.66	7.82	8.30	8.25	8.42
9	7.46	7.50	7.68	7.86	8.01
10	7.66	7.78	8.09	8.15	8.45
Average $\bar{c}$ Standard Error	7.33 ± 0.16	7.46 ± 0.16	7.66 ± 0.15	7.85 ± 0.12	8.01 ± 0.13

Table 38

Diet D

(R.B.C.in millions/mm^3)

Rat No.	Weeks				
	0	1	2	3	4
1	7.01	7.09	7.41	7.79	8.30
2	7.82	8.02	8.24	8.39	8.34
3	7.68	7.58	7.90	8.09	8.35
4	7.59	7.91	8.15	8.22	8.44
5	7.61	7.84	8.46	8.64	8.36
6	7.81	7.73	7.60	8.03	8.21
7	7.52	7.72	7.90	8.02	8.55
8	7.69	7.79	7.68	7.86	8.01
9	7.04	7.15	7.21	8.22	8.33
10	7.25	7.45	7.94	8.46	8.55
Average $\bar{c}$	7.50±	7.63±	7.85±	8.17±	8.34±
Standard Error	0.09	0.09	0.12	0.08	0.05

Table 39

Diet E

(R.B.C. in millions/mm^3)

Rat No.	Weeks				
	0	1	2	3	4
1	7.43	7.59	7.68	8.10	8.96
2	7.63	7.90	8.17	8.10	8.48
3	7.81	7.83	7.97	7.45	7.75
4	7.38	7.90	8.49	8.44	8.13
5	7.41	7.52	7.61	7.78	7.98
6	7.37	7.48	8.08	8.12	8.41
7	7.48	7.50	7.64	7.70	7.86
8	7.60	7.64	7.73	7.82	8.20
9	7.38	7.82	7.43	7.54	8.00
10	7.52	7.84	7.85	7.62	7.64
Average $\bar{c}$	7.50	7.70	7.86	7.67	8.14
Standard Error	± 0.07	± 0.05	± 0.10	± 0.10	± 0.13

Table 40

Haemoglobin concentration of animals receiving diets A, B, C, D and E

Diet A

Rat No.	Weeks				
	0	1	2	3	4
1	13.4	13.7	13.6	13.8	13.8
2	13.2	13.4	13.6	13.6	13.7
3	13.4	13.3	13.6	13.8	13.8
4	13.5	13.7	13.8	14.1	14.4
5	14.0	13.9	14.1	14.2	14.3
6	13.5	13.8	13.6	13.7	14.1
7	13.4	13.5	13.8	14.1	14.2
8	13.2	13.3	13.3	13.4	14.1
9	13.5	14.1	14.2	14.3	14.5
10	13.9	14.1	14.1	14.2	14.4
Average $\bar{c}$	13.5	13.7	13.8	13.9	14.1
Standard Error	± 0.09	± 0.09	± 0.09	± 0.08	± 0.08

Table 41

Diet B

Rat No.	Weeks				
	0	1	2	3	4
1	13.3	13.6	13.8	13.8	14.4
2	13.5	13.7	14.1	14.4	14.6
3	13.8	14.0	13.8	14.6	14.8
4	13.2	13.3	13.2	13.4	13.4
5	13.8	13.7	13.9	14.1	14.2
6	13.5	13.7	14.1	14.5	14.6
7	13.4	13.5	13.7	13.7	14.1
8	13.5	13.6	13.8	14.1	14.7
9	13.2	13.5	13.7	13.8	14.2
10	14.1	14.2	14.2	14.3	14.6
Average $\bar{c}$ Standard Error	13.5 ± 0.09	13.7 ± 0.08	13.8 ± 0.09	14.1 ± 0.12	14.4 ± 0.13

Table 42

Diet C

Rat No.	Weeks				
	0	1	2	3	4
1	14.0	14.1	14.2	14.0	14.4
2	13.5	13.7	13.8	13.4	14.5
3	13.6	13.7	14.8	14.3	13.5
4	13.3	14.4	14.4	14.6	14.5
5	13.8	14.0	14.2	14.5	15.0
6	14.1	14.2	14.3	14.2	14.5
7	13.5	14.1	14.2	13.8	14.6
8	13.2	13.3	13.9	14.0	14.6
9	13.6	13.8	14.1	14.4	15.0
10	13.4	13.6	13.8	14.5	14.8
Average $\bar{c}$	13.6	13.9	14.1	14.3	14.5
Standard Error	± 0.09	± 0.10	± 0.06	± 0.08	± 0.13

Table 43

Diet D

Rat No.	Weeks				
	0	1	2	3	4
1	13.3	13.6	14.1	14.5	15.0
2	13.7	13.9	13.6	14.0	14.1
3	14.5	14.8	15.0	15.0	15.0
4	14.6	14.8	14.5	14.0	14.1
5	13.1	13.9	14.2	14.4	14.6
6	13.7	13.9	14.0	14.5	14.8
7	13.7	14.0	14.7	14.7	14.6
8	14.6	15.0	15.0	15.0	15.0
9	13.8	14.0	14.5	14.5	15.0
10	13.3	13.6	14.1	15.0	15.6
Average $\bar{c}$	13.8	14.1	14.4	14.6	14.8
Standard Error	$\pm \frac{0.17}{\sqrt{}}$	$\pm \frac{0.16}{\sqrt{}}$	$\pm \frac{0.14}{\sqrt{}}$	$\pm \frac{0.11}{\sqrt{}}$	$\pm \frac{0.14}{\sqrt{}}$

Table 44

Diet E

Rat No.	Weeks				
	0	1	2	3	4
1	13.2	13.2	13.6	14.0	14.5
2	14.5	14.2	14.0	14.5	15.0
3	13.7	13.8	14.0	14.5	15.0
4	14.2	14.5	14.5	14.5	15.0
5	13.8	13.8	14.1	14.5	14.8
6	14.1	14.2	14.5	15.0	15.4
7	13.4	13.5	13.8	14.6	14.8
8	14.1	14.5	14.6	14.8	14.8
9	13.7	14.6	15.0	15.4	15.6
10	14.5	15.0	14.8	15.0	15.3
Average $\bar{c}$	13.9	14.1	14.3	14.7	15.2
Standard Error	$\pm$ 0.14	$\pm$ 0.17	$\pm$ 0.14	$\pm$ 0.12	$\pm$ 0.10

Table 45

Plasma protein concentration of animals maintained on Diets A, B, C, D and E (values in g./100 ml.)

Rat No.	Diets				
	A	B	C	D	E
1	6.2	5.6	6.8	6.1	6.6
2	5.8	6.2	6.2	6.5	6.0
3	5.6	5.8	5.8	6.6	6.2
4	6.3	5.8	7.0	5.8	5.8
5	6.0	6.2	6.4	6.0	6.0
6	6.4	6.0	6.2	6.2	6.1
7	5.8	5.8	6.6	6.3	6.3
8	6.0	5.9	6.8	5.9	5.7
9	6.3	6.1	6.4	6.5	6.1
10	5.8	6.0	6.3	7.0	6.4
Average $\bar{c}$ Standard Error	$6.0 \pm \frac{}{0.18}$	$5.9 \pm \frac{}{0.24}$	$6.5 \pm \frac{}{0.11}$	$6.3 \pm \frac{}{0.11}$	$6.1 \pm \frac{}{0.08}$

Table 46

Summarised data* on red blood cell concentration recorded in respect of groups of rats maintained on diets A, B, C, D and E (Vide Tables 35 to 39)

R.B.C. in millions/mm^3

Diets	No. of animals	Weeks				
		0	1	2	3	4
A	10	6.69± 0.10	6.79± 0.13	7.09± 0.13	7.49± 0.16	7.77± 0.14
B	10	6.85± 0.14	7.06± 0.16	7.33± 0.09	7.62± 0.08	7.86± 0.23
C	10	7.33± 0.16	7.46± 0.16	7.66± 0.15	7.85± 0.12	8.01± 0.13
D	10	7.50± 0.09	7.63± 0.09	7.85± 0.12	8.17± 0.08	8.34± 0.05
E	10	7.50± 0.07	7.70± 0.05	7.86± 0.10	7.67± 0.10	8.14± 0.13

* Mean values (10 animals/group) with standard error.

Table 47

Summarised data* on haemoglobin concentration recorded in respect of groups of rats maintained on diets A, B, C, D and E

(Plasma protein and haemoglobin in g./100 ml. average values)

Diets	No.of animals	Plasma Protein	0	1	2 2	3 3	4
A	10	6.0± 0.18	13.5± 0.09	13.7± 0.09	13.8± 0.09	13.9± 0.08	14.1± 0.08
B	10	5.9± 0.24	13.5± 0.09	13.7± 0.08	13.8± 0.09	14.1± 0.12	14.4± 0.13
C	10	6.5± 0.11	13.6± 0.09	13.9± 0.10	14.1± 0.06	14.3± 0.08	14.5± 0.13
D	10	6.3± 0.11	13.8± 0.17	14.1± 0.16	14.4± 0.14	14.6± 0.11	14.8± 0.14
E	10	6.1± 0.08	13.9± 0.14	14.1± 0.17	14.3± 0.14	14.7± 0.12	15.2± 0.10

* Mean values (10 animals/group) with standard error.

Table 48

Analysis of variance--Red blood cells

Source	df	SS.	MSS.	F.
Between treatments	4	2.1	0.525	15.39**
Error	45	1.5387	0.0341	
Total	49	3.6387		

** Significant at 1% level.

Critical difference: 0.32 at 5% level.
0.42 at 1% level.

Mean values: A = 7.77, B = 7.86, C = 8.01, D=8.34, E = 8.14.

Table 49

Analysis of variance--Haemoglobin concentration (g./100 ml.)

Source	df.	SS.	MSS.	F.
Between treatments	4	4.852	1.213	8.19**
Error	45	6.678	0.148	
Total	49	11.530		

** Significant at 1% level.

Critical difference: 0.32 at 5% level.
0.42 at 1% level.

Mean values: A = 14.1, B = 14.4, C = 14.5, D = 14.8, E = 15.2

Table 50

Analysis of variance--Plasma protein

Source	df.	SS.	MSS.	F.
Between treatments	4	1.60	0.40	1.90 N.S.
Error	45	9.38	0.20	
Total	49	10.98		

N.S.= Not significant.

Table 51

Glutamic-Oxalo acetic transaminase and glutamic pyruvic transaminase levels in serum and liver of animals maintained on diets, A, B, C, D and E

Diet A

Rat No.	Glutamic-Oxalo acetic transaminase		Glutamic pyruvic transaminase	
	Serum units/ml.	Liver units/g. liver	Serum units/ml.	Liver units/g. liver
1	145.0	454.0	198.0	632.0
2	131.0	358.0	212.0	584.0
3	112.0	490.0	215.0	512.0
4	138.0	450.0	209.0	488.0
5	106.0	564.0	188.0	620.0
6	110.0	515.0	210.0	438.0
Average $\bar{c}$ Standard Error	123.7 ± 6.71	471.8 ± 28.53	205.3 ± 4.17	545.7 ± 31.88

Table 52

Diet B

Rat No.	Glutamic-Oxalo acetic transaminase		Glutamic pyruvic transaminase	
	Serum Units/ml.	Liver units/g. liver	Serum units/ml.	Liver units/g. liver
1	115.0	484.0	210.0	652.0
2	120.0	495.0	198.0	688.0
3	113.0	398.0	185.0	701.0
4	108.0	438.0	201.0	515.0
5	111.0	355.0	165.0	526.0
6	124.0	437.0	201.0	498.0
Average $\bar{c}$ Standard Error	$115.2 \pm \frac{}{2.41}$	$549.7 \pm \frac{}{21.41}$	$193.3 \pm \frac{}{6.55}$	$596.7 \pm \frac{}{36.16}$

Table 53

Diet C

Rat No.	Glutamic-Oxalo acetic transaminase		Glutamic pyruvic transaminase	
	Serum units/ml.	Liver units/g. liver	Serum units/ml.	Liver units/g. liver
1	144.0	458.0	182.0	648.0
2	135.0	392.0	196.0	560.0
3	108.0	468.0	201.0	486.0
4	110.0	542.0	180.0	640.0
5	125.0	449.0	198.0	518.0
6	102.0	436.0	168.0	498.0
Average $\bar{c}$	120.7	457.5	187.5	558.3
Standard Error	$\pm$ 6.81	$\pm$ 20.06	$\pm$ 16.64	$\pm$ 28.99

Table 54

Diet D

Rat No.	Glutamic-Oxalo acetic transaminase		Glutamic pyruvic transaminase	
	Serum units/ml.	Liver units/g. liver	Serum units/ml.	Liver units/g. liver
1	114.0	415.0	196.0	645.0
2	130.0	315.0	188.0	538.0
3	105.0	452.0	205.0	448.0
4	100.0	584.0	198.0	640.0
5	125.0	438.0	210.0	512.0
6	140.0	358.0	185.0	548.0
Average $\bar{c}$ Standard Error	119.0± 6.27	427.0± 37.79	197.0± 3.91	555.2± 31.07

Table 55

Diet E

Rat No.	Glutamic-Oxalo acetic transaminase		Glutamic pyruvic transaminase	
	Serum units/ml.	Liver units/g. liver	Serum units/ml.	Liver units/g. liver
1	116.0	201.0	189.0	648.0
2	118.0	498.0	205.0	712.0
3	109.0	404.0	198.0	537.0
4	125.0	312.0	194.0	412.0
5	134.0	448.0	209.0	448.0
6	150.0	512.0	208.0	568.0
Average $\bar{c}$ Standard Error	125.3 ± 6.03	395.8 ± 48.89	200.5 ± 3.31	554.2 ± 46.79

Table 56

Summarised data* on glutamic-oxalo acetic transaminase, Glutamic pyruvic transaminase levels in serum and liver of rats fed diets A, B, C, D and E.

Diets	No.of animals	Glutamic-Oxalo acetic transaminase		Glutamic pyruvic transaminase	
		Serum units/ml.	Liver units/g.liver	Serum units/ml.	Liver units/g.liver
A	6	123.7± 6.71	471.8± 28.53	205.3± 4.17	545.7± 31.85
B	6	115.2± 2.41	549.7± 21.43	193.3± 6.55	596.7± 36.16
C	6	120.7± 6.81	457.5± 20.06	187.5± 16.64	588.3± 28.99
D	6	119.0± 6.27	427.0± 37.79	197.0± 3.91	555.2± 31.07
E	6	125.0± 6.03	395.8± 48.89	200.5± 3.31	554.2± 46.79

* Mean values (6 animals/group) with standard error.

Table 57

Analysis of variance--Glutamic-Oxalo acetic transaminases in serum (units/ml.)

Source	df.	SS.	MSS.	F.
Between treatments	4	382.5	95.625	0.46*
Error	25	5186.9	207.476	
Total	29	5569.4		

* Not significant

Table 58

Analysis of variance--Glutamic-Oxalo acetic transaminases in liver (units/g.)

Source	df.	SS.	MSS.	F.
Between treatments	4	20604.0	5151.0	0.78 *
Error	25	164851.0	6594.04	
Total	29	185455.0		

* Not significant

Table 59

Analysis of variance--Glutamic pyruvic transaminases in serum (units/ml.)

Source	df.	SS.	MSS.	F.
Between treatments	4	11110.2	277.55	2.02*
Error	25	3437.7	137.51	
Total	29	4547.9		

* Not significant

Table 60

Analysis of variance--Glutamic pyruvic transaminases in liver (units/g.)

Source	df.	SS.	MSS.	F.
Between treatments	4	954.0	238.5	0.29*
Error	25	20263000	8105.2	
Total	29	203584.0		

* Not significant

Table 61

Data on liver glycogen content of animals maintained on diets A, B, C, D and E

(Values in g./100 g. tissue)

Rat No.	Diets				
	A	B	C	D	E
	Liver(g.%)	Liver (g.%)	Liver (g.%)	Liver (g.%)	Liver (g.%)
1	1.95	1.91	2.01	1.33	2.14
2	2.21	1.91	2.29	2.03	2.18
3	2.17	1.99	2.48	2.41	2.16
4	2.25	1.96	1.77	2.38	2.95
5	1.90	2.26	2.81	2.75	2.15
6	1.82	1.91	2.85	2.42	2.38
Average $\bar{c}$ Standard Errer	2.05± 0.07	1.99± 0.06	2.35± 0.07	2.22± 0.20	2.32± 0.13

Table 62

Summarised data* on glycogen content of liver recorded in respect of animal maintained on diets A, B, C, D and E.

(Values in g./100 g. tissue)

Diets	No.of animals	Body weight (g.)	Fresh weight of liver(g.)	Liver glycogen (g.%)
A	6	55.4± 2.14	3.38± 0.22	2.05± 0.07
B	6	54.0± 2.22	2.97± 0.14	1.99± 0.06
C	6	97.2± 4.81	5.43± 0.38	2.35± 0.07
D	6	77.9± 0.82	5.13± 0.31	2.22± 0.20
E	6	82.2± 1.89	5.03±	2.32± 0.13

* Mean values (6 animals/group) with standard error.

Table 63

Analysis of variance--Liver glycogen

Source	df.	SS.	MSS.	F.
Between treatments	4	0.6289	0.1572	1.10*
Error	25	3.4266	0.1427	
Total	29			

* Not significant

Table 64

Liver protein and liver fat contents of animals maintained on diets A, B, C, D and E.

Diet A

Rat No.	Body wt.	Fresh wt. of liver		Total lipids		Total Protein	
		Wt. in g.	% of body wt.	% of fresh wt.	mg/100g. rat	% of fresh wt.	mg/100g. rat
1	54	2.85	5.28	4.58	241.7	13.74	725.2
2	40	3.25	8.12	3.02	245.4	16.45	1116.3
3	56	3.60	6.43	5.02	322.7	11.48	738.0
4	55	3.36	6.11	4.54	227.3	10.58	646.3
5	54	3.66	6.78	3.28	222.3	20.15	1365.7
6	52	3.89	7.49	6.44	481.7	15.48	1158.0
7	56	2.64	4.71	8.02	378.1	15.32	722.2
8	60	3.48	5.80	5.08	294.6	12.84	744.7
9	65	3.48	5.35	5.14	275.2	13.35	714.7
10	62	3.60	5.81	4.08	236.9	14.58	846.6
Average $\bar{c}$ Standard Error	55.4± 2.14	3.38± 0.22	6.19± 0.33	4.92± 0.46	292.6± 26.10	14.39± 0.86	877.8± 77.41

Table 65

Diet B

Rat No.	Body wt.	Fresh wt. of liver		Total lipids		Total Protein	
		Wt. in g.	% of body wt.	% of fresh wt.	mg/100g. rat	% of fresh wt.	mg/100g. rat
1	49	2.59	5.28	5.48	289.6	13.85	732.1
2	51	2.91	5.70	6.04	344.6	12.01	685.3
3	40	2.30	5.75	8.82	507.2	10.54	606.1
4	49	2.93	5.78	6.42	383.9	12.12	724.7
5	59	3.59	6.08	3.08	187.4	13.58	826.3
6	59	3.59	6.29	4.14	260.7	14.11	888.7
7	64	3.08	4.81	5.12	246.4	13.88	667.9
8	54	3.17	5.87	6.18	362.8	14.12	828.9
9	60	2.37	3.95	6.58	259.9	15.32	605.1
10	55	3.20	5.61	6.41	359.8	16.14	906.1
Average $\bar{c}$	54	2.97	5.51	5.83	320.2	13.57	747.1
Standard Error	± 2.22	± 0.14	± 0.22	± 0.49	± 32.35	± 0.52	± 34.82

Table 66

Diet C

Rat No.	Body wt.	Fresh wt. of liver		Total lipids		Total Protein	
		Wt. in g.	% of body wt.	% of fresh wt.	mg/100g. rat	% of fresh wt.	mg/100g. rat
1	67	3.40	5.07	4.15	210.6	14.58	739.9
2	80	5.11	6.39	3.45	220.4	13.84	884.0
3	93	4.85	5.21	2.86	149.1	15.22	793.7
4	98	5.38	5.49	4.05	222.3	16.84	924.5
5	114	5.28	4.63	4.25	196.8	15.02	695.7
6	97	4.11	4.24	3.18	134.7	14.11	597.8
7	97	5.64	5.81	3.28	190.7	12.01	698.3
8	99	6.05	6.11	2.14	130.8	10.85	663.0
9	118	7.04	5.97	6.35	378.8	14.43	860.9
10	109	7.42	6.81	4.01	272.9	12.12	825.0
Average $\bar{c}$	97.2±	5.43±	5.57±	3.77±	210.7±	13.90±	768.3±
Standard Error	4.81	0.38	0.25	0.35	23.31	0.56	33.55

Table 67

Diet D

Rat No.	Body wt.	Fresh wt. of liver		Total lipids		Total protein	
		Wt. in g.	% of body wt.	% of fresh wt.	mg/100g. rat	% of fresh wt.	mg/100g. rat
1	83	5.12	6.17	4.44	273.9	14.14	872.2
2	87	3.84	4.41	3.15	139.0	15.32	676.2
3	92	3.94	4.28	5.85	250.5	16.84	721.2
4	102	4.49	4.40	4.32	190.2	15.13	666.0
5	89	7.14	8.02	4.22	338.5	13.85	1111.1
6	78	4.85	6.22	3.84	238.8	12.64	785.9
7	62	5.05	8.14	2.08	169.4	13.15	1071.1
8	55	5.32	9.67	5.48	530.1	14.86	1437.3
9	63	6.01	9.54	6.12	583.8	15.12	1442.4
10	68	5.52	8.16	8.32	431.8	14.14	1147.8
Average $\bar{c}$ Standard Error	77.9± 4.82	5.13± 0.31	6.90± 0.92	4.48± 0.39	314.6± 48.55	14.52± 0.37	993.1 88.53

Table 68

Diet E

Rat No.	Body wt.	Fresh wt. of liver		Total lipids		Total protein	
		Wt. in g.	% of body wt.	%of fresh wt.	mg/100g. rat	%of fresh wt.	mg/100g. rat
1	76	4.89	6.43	6.48	416.9	14.28	918.8
2	75	4.58	6.03	4.53	276.6	15.38	939.2
3	88	5.09	5.78	2.31	133.6	16.01	926.0
4	95	6.53	6.87	2.08	142.9	15.11	1038.6
5	83	5.59	6.73	4.14	278.8	12.48	840.5
6	83	5.43	6.54	5.48	358.5	13.12	567.8
7	77.0	5.58	7.25	4.04	292.8	15.84	1147.9
8	80.0	6.04	7.55	3.82	288.4	13.21	997.3
9	82.0	5.64	6.88	5.14	353.5	16.01	1101.2
10	83.0	5.55	6.69	4.35	290.9	12.34	825.1
Average ± Standard Error	82.2 ± 1.89	5.49 ± 0.17	6.67 ± 0.16	4.24 ± 0.42	283.3 ± 28.04	14.38 ± 0.46	930.2 ± 52.07

Table 69

Diet

Summarised data* on liver protein and liver fat contents of animals maintained on Diets A, B, C, D and E (Vide Tables 64 to 68)

Diets	No. of animals	Weight of liver		Total lipids		Total protein	
		Fresh wt. (g.)	% of body wt.	% of fresh wt.	mg/100 g. rat	% of fresh wt.	mg./100 g.rat
A	10	3.38± 0.22	6.19± 0.33	4.92± 0.46	292.6± 26.10	14.39± 0.86	877.8± 77.41
B	10	2.97± 0.14	5.51± 0.22	5.83± 0.49	320.2± 32.35	13.57± 0.52	747.1± 34.82
C	10	5.43± 0.38	5.57± 0.25	3.77± 0.35	210.7± 23.31	13.90± 0.56	768.3± 33.55
D	10	5.13± 0.31	6.90± 0.92	4.48± 0.39	314.6± 48.55	14.52± 0.37	993.1± 88.53
E	10	5.49± 0.17	6.67± 0.16	4.24± 0.42	283.3± 28.04	14.38± 0.46	930.2± 52.07

* Mean values (10 animals/group) with standard error

Table 70

Analysis of variance - Liver fat percentage on fresh basis

Source	df.	SS.	MSS.	F.
Between treatments	4	24.2789	6.0697	4.34**
Error	45	62.9586	1.3991	
Total	49	87.2375		

** Significant at 1% level

Critical difference: 1.05 at 5% level
1.37 at 1% level

Mean values: A = 4.92, B = 5.83, C = 3.77, D = 4.48, E = 4.44

Table 71

Analysis of variance - Liver protein - percentage on fresh weight basis

Source	df.	SS.	MSS.	F.
Between treatments	4	6.5055	1.6263	0.48*
Error	45	151.7634	3.3725	
Total	49	158.2689		

* Not significant

Table 72

Internal organ weights of animals maintained on diets A, B, C, D and E.

Diet A

Rat No.	Body Wt. g.	Body surface cm^2	Wt. of organ in g. per 100 cm^2 body surface			
			Liver	Kidney	Spleen	Heart
1	54.0	137.3	2.0760	0.4031	0.1894	0.1505
2	40.0	113.7	2.9719	0.4824	0.1756	0.2168
3	56.0	140.4	2.5650	0.5318	0.1588	0.1788
4	55.0	138.9	2.4214	0.4583	0.1716	0.1949
5	54.0	137.3	2.6652	0.4445	0.1466	0.2043
6	52.0	134.3	2.9000	0.4027	0.1477	0.1970
7	56.0	140.4	1.8794	0.3431	0.0664	0.1496
8	60.0	146.3	2.3782	0.4557	0.1363	0.1927
9	65.0	140.4	2.4768	0.4448	0.1271	0.1975
10	62.0	149.1	2.4171	0.3340	0.1376	0.1656
Average $\bar{c}$	55.5	137.8	2.4751	0.4300	0.1457	0.1848
Standard Error	± 2.14	± 1.75	± 0.1054	± 0.0192	± 0.0105	± 0.0072

Table 73

Diet B

Rat No.	Body Wt. g.	Body surface cm^2	Wt. of organs in g. per 100 cm^2 body surface			
			Liver	Kidney	Spleen	Heart
1	49.0	129.8	1.9959	0.3693	0.1656	0.1355
2	51.0	132.6	2.1200	0.4377	0.2059	0.1587
3	40.0	113.7	2.0254	0.3927	0.1848	0.1486
4	49.0	129.5	2.2631	0.4375	0.1963	0.1550
5	59.0	144.8	2.4809	0.5163	0.1475	0.2108
6	59.0	144.8	2.4829	0.5020	0.1688	0.1743
7	64.0	152.1	2.0237	0.4538	0.1542	0.1623
8	54.0	137.3	2.3098	0.4672	0.1667	0.1488
9	60.0	146.3	1.6187	0.3608	0.0712	0.1433
10	55.0	138.9	2.3032	0.4314	0.1574	0.1466
Average $\bar{c}$	54.0	136.9	2.1624	0.4369	0.1618	0.1584
Standard Error	2.22	3.51	0.0829	0.0164	0.0117	0.0067

Table 74

Diet C

Rat No.	Body Wt. g.	Body surface cm^2	Wt. of organs in g. per 100 cm^2 body surface			
			Liver	Kidney	Spleen	Heart
1	67	156.3	2.1779	0.5877	0.2878	0.2197
2	80	173.9	2.9397	0.3948	0.2144	0.1889
3	93	190.3	2.5477	0.5109	0.2106	0.1974
4	98	196.3	2.6728	0.4347	0.2201	0.1863
5	114	215.0	2.4567	0.4016	0.1896	0.1814
6	97	195.1	2.1059	0.3865	0.1860	0.1694
7	97	195.1	2.8887	0.3941	0.2086	0.1755
8	99	197.5	3.0628	0.4764	0.2537	0.2125
9	118	219.5	3.2078	0.4544	0.2988	0.1968
10	109	209.2	3.5465	0.4594	0.2495	0.2256
Average $\bar{c}$	97.2±	194.2±	2.7603±	0.4507±	0.2319±	0.1953±
Standard Error	4.81	7.20	0.4550	0.0207	0.0141	0.0054

Table 75

Diet D

Rat No.	Body Wt. g.	Body surface cm^2	Wt. of organs in g. per 100 cm^2 body surface			
			Liver	Kidney	Spleen	Heart
1	83	177.7	2.8817	0.5114	0.1601	0.2007
2	87	182.8	2.0995	0.4043	0.1334	0.1992
3	92	189.0	2.0841	0.4569	0.1955	0.1844
4	102	201.1	2.2371	0.5259	0.1701	0.1796
5	89	185.3	3.8549	0.2954	0.1671	0.2338
6	78	171.2	2.8314	0.5490	0.1810	0.1996
7	62	149.1	3.3870	0.6593	0.1951	0.2529
8	55	138.9	3.8333	0.6574	0.2402	0.2565
9	63	150.5	3.9948	0.6642	0.1945	0.3077
10	68	157.7	3.1635	0.7309	0.2202	0.3020
Average $\bar{c}$ Standard Error	77.9± 4.82	170.3± 6.43	3.0707± 0.5160	0.5455± 0.0424	0.1857± 0.0105	0.2316± 0.0142

Table 76

Diet E

Rat No.	Body Wt. g.	Body surface cm^2	Wt. of organs in g. per 100 cm^2 body surface			
			Liver	Kidney	Spleen	Heart
1	76	168.6	2.9053	0.4737	0.1591	0.2156
2	75	167.2	2.7392	0.5687	0.1555	0.2087
3	88	184.1	2.7688	0.5138	0.1641	0.2185
4	95	192.7	3.3899	0.5877	0.1465	0.2235
5	83	177.7	3.1458	0.5814	0.1529	0.2228
6	83	177.7	3.0545	0.5737	0.1519	0.2038
7	77	109.9	5.0810	0.9108	0.2366	0.3443
8	80	173.8	3.4771	0.6352	0.1577	0.2038
9	82	176.4	3.1984	0.5433	0.1470	0.2354
10	83	177.7	3.1244	0.4319	0.1688	0.2274
Average $\bar{c}$	82.2±	170.6±	3.2884±	0.5760±	0.1640±	0.2304±
Standard Error	1.89	7.13	0.5865	0.0173	0.0105	0.0045

Table 77

Summarised data* on internal organ weights recorded in respect of rats maintained on diets A, B, C, D and E. (Vide Tables 72-76)

Diets	Body Wt. g.	Body surface cm^2	Wt. of organs in g. per 100 cm^2 body surface			
			Liver	Kidney	Spleen	Heart
A	55.4± 1.75	137.8± 1.75	2.4751± 0.1054	0.4300± 0.0192	0.1457± 0.0105	0.1848± 0.0072
B	54.0± 2.22	136.9± 3.51	2.1624± 0.0829	0.4369± 0.0164	0.1618± 0.0117	0.1584± 0.0067
C	97.2± 4.81	194.2± 7.20	2.7603± 0.4550	0.4507± 0.0200	0.2319± 0.0141	0.1953± 0.0054
D	77.9± 4.82	170.3± 6.43	3.0707± 0.5160	0.5455± 0.0424	0.1857± 0.0105	0.2316± 0.0142
E	82.2± 1.89	170.6± 7.13	3.2884± 0.5865	0.5760± 0.0173	0.1640± 0.0105	0.2304± 0.0045

* Mean values (10 animals/group) with standard error

Table 78

Analysis of variance - Weight of kidney in gram

Source	df.	SS.	MSS.	F.
Between treatments	4	0.1846	0.0462	5.02**
Error	45	0.4160	0.0092	
Total	49	0.6006		

** Significant at 1% level

Critical difference: 0.0706 at 5% level
0.0929 at 1% level

Mean values: A = 0.4300, B = 0.4369, C = 0.4500, D = 0.5455, E = 0.5760.

Table 79

Analysis of variance - Weight of heart in gram

Source	df.	SS.	MSS.	F.
Between treatments	4	0.0364	0.0091	7.58**
Error	45	0.0526	0.0012	
Total	49	0.0890		

** Significant at 1% level

Critical difference: 0.0322 at 5% level
0.0424 at 1% level

Mean values: A = 0.1848, B = 0.1584, C = 0.1953, D = 0.2316, E = 0.2304.

Table 80

Analysis of variance - Weight of spleen in gram

Source	df.	SS.	MSS.	F.
Between treatments	4	0.0448	0.0112	10.00**
Error	45	0.0505	0.0011	
Total	49	0.0953		

** Significant at 1% level

Critical difference: 0.0334 at 5% level
0.0439 at 1% level

Mean values: A = 0.1457, B = 0.1618, C = 0.2319, D = 0.1857, E = 0.1640.

Table 81

Analysis of variance - Weight of liver in gram

Source	df.	SS.	MSS.	F.
Between treatments	4	7.8924	1.9731	7.15**
Error	45	12.4192	0.2760	
Total	49	20.3116		

** Significant at 1% level

Critical difference: 0.4673 at 5% level
0.6151 at 1% level

Mean values: A = 2.4751, B = 2.1624, C = 2.7603, D = 3.0707, E = 3.2884.

Table 82

Caecal weights of animals maintained on diets A, B, C, D and E.

Diet A

Rat No.	Body Wt. (g.)	Wt. of Caecum with contents (g.)	Wt. of Caecum with contents/ 100g. body wt. (g.)	Wt. of Caecum without contents (g.)	Wt. of Caecum without contents/ 100g. body Wt. (g.)
5	54.0	1.68	3.12	0.21	0.39
6	52.0	1.52	2.93	0.20	0.39
7	56.0	1.38	2.45	0.19	0.35
8	60.0	1.69	2.82	0.22	0.36
9	65.0	1.34	2.06	0.27	0.42
10	62.0	1.50	2.50	0.26	0.43
Average $\bar{c}$					
Standard Error	58.2± 2.04	1.52± 0.06	2.65± 0.49	0.23± 0.01	0.39± 0.01

Table 83

Diet B

Rat. No.	Body Wt.(g.)	Wt. of Caecum with contents (g.)	Wt. of Caecum with contents/ 100g. body wt. (g.)	Wt.of Caecum without contents (g.)	Wt. of Caecum without contents/ 100g. body Wt. (g.)
5	59.0	6.29	9.12	0.61	0.88
6	59.0	3.23	5.66	0.44	0.77
7	64.0	5.27	8.24	0.53	0.79
8	54.0	4.11	7.61	0.31	0.56
9	60.0	4.00	7.28	0.37	0.68
10	55.0	3.27	5.74	0.31	0.54
Average $\bar{c}$ Standard Error	58.5± 1.48	4.36± 0.49	7.28± 0.56	0.43± 0.05	0.70± 0.17

Table 84

Diet C

Rat No.	Body Wt.(g.)	Wt. of Caecum with contents (g.)	Wt. of Caecum with contents/ 100g. body wt. (g.)	Wt. of Caecum without contents (g.)	Wt. of Caecum without contents/ 100g. body wt. (g.)
5	114.0	1.25	1.09	0.29	0.25
6	97.0	1.03	1.06	0.35	0.36
7	97.0	1.24	1.28	0.23	0.24
8	99.0	1,02	1.04	0.27	0.27
9	118.0	1.23	1.04	0.31	0.26
10	109.0	0.95	0.87	0.24	0.22
Average $\bar{c}$ Standard Error	105.7± 3.77	1.12± 0.05	1.06± 0.05	0.28± 0.02	0.27± 0.02

Table 85

Diet D

Rat No.	Body Wt. (g.)	Wt. of Caecum with contents (g.)	Wt. of Caecum with contents/ 100g. body wt. (g.)	Wt. of Caecum without contents (g.)	Wt. of Caecum without contents/ 100 g. body wt. (g.)
5	89.0	1.05	1.18	0.25	0.28
6	78.0	1.65	2.11	0.21	0.27
7	62.0	1.58	2.55	0.15	0.24
8	55.0	1.45	2.63	0.19	0.34
9	63.0	1.86	2.95	0.40	0.64
10	68.0	1.85	2.71	0.31	0.46
Average $\bar{c}$ Standard Error	69.2± 5.04	1.57± 0.12	2.36± 0.26	0.25± 0.04	0.37± 0.06

Table 86

Diet E

Rat No.	Body Wt. (g.)	Wt. of Caecum with contents (g.)	Wt. of Caecum with contents/ 100g. body wt. (g.)	Wt. of Caecum without contents (g.)	Wt. of Caecum without contents/ 100g. body wt. (g.)
1	76.0	1.54	2.03	0.22	0.29
2	75.0	1.06	1.41	0.29	0.38
3	88.0	1.35	1.53	0.35	0.39
4	95.0	1.29	1.35	0.21	0.22
5	83.0	1.86	2.24	0.21	0.25
6	83.0	1.58	1.90	0.23	0.28
Average $\bar{c}$	83.3±	1.45±	1.74±	0.25±	0.30±
Standard Error	3.06	0.11	0.14	0.02	0.03

Table 87

Summarised data* on caecal weights of rats fed on diets A, B, C, D and E.

Diets	Body Wt. (g.)	Wt. of Caecum with contents (g.)	Wt. of Caecum with contents/ 100g. body wt. (g.)	Wt. of Caecum without contents (g.)	Wt. of Caecum without contents/ 100g. body wt. (g.)
A	58.2± 2.04	1.52± 0.06	2.65± 0.49	0.23± 0.01	0.39± 0.01
B	58.5± 1.48	4.36± 0.49	7.28± 0.56	0.43± 0.05	0.70± 0.17
C	105.7± 3.77	1.12± 0.05	1.06± 0.05	0.28± 0.02	0.27± 0.02
D	69.2± 5.04	1.57± 0.12	2.36± 0.26	0.25± 0.04	0.37± 0.04
E	83.3± 3.06	1.45± 0.11	1.74± 0.14	0.25± 0.02	0.30± 0.03

* Mean values (6 animals/group) with standard error

Table 88

Analysis of variance - weight of caecum without contents/100g. body wt.

Source	df.	SS.	MSS.	F.
Between treatments	4	0.7208	0.1802	18.2020**
Error	25	0.2487	0.0099	
Total	29	0.9695		

** Significant at 1% level

Critical difference: 0.0801 at 5% level
0.1083 at 1% level

Mean values: A = 0.39, B = 0.70, C = 0.27, D = 0.37, E = 0.30

Table 89

Analysis of variance - weight of caecum with contents/100g. body weight

Source	df.	SS.	MSS.	F.
Between treatments	4	14.8700	36.2175	69.99**
Error	25	12.9359	0.5174	
Total	29	27.8059		

** Significant at 1% level

Critical difference: 0.71 at 5% level
0.96 at 1% level

Mean values: A = 2.65, B = 7.28, C = 1.06, D = 2.36, E = 1.74.

Table 90

Weights of pancreas of animals maintained on diets A, B, C, E and E.

Diet A

Rat No.	Body wt. (g)	Wt. of pancreas (g)	Wt. of pancreas/ 100g. rat (g)	pancreas dry wt. (g)	Moisture %
1	54	0.2414	0.4642	0.1234	48.88
2	46	0.2117	0.5292	0.0915	56.77
3	56	0.2820	0.5035	0.1454	48.44
4	55	0.2204	0.4007	0.1842	16.42
5	54	0.3130	0.5796	0.0914	70.83
6	52	0.2239	0.4305	0.1315	41.27
7	56	0.3046	0.5439	0.0910	70.12
8	60	0.3814	0.6356	0.0995	73.92
9	65	0.2772	0.4264	0.0914	67.03
10	62	0.3482	0.5803	0.1310	62.43
Average $\bar{c}$	55.4	0.2804	0.5094	0.1178	55.51
Standard Error	± 2.14	± 0.0168	± 0.0246	± 0.1001	± 5.58

Table 91

Diet B

Rat No.	Body wt. (g)	Wt. of pancreas (g)	Wt. of pancreas/ 100g. rat (g)	pancreas dry wt. (g)	Moisture %
1	49	0.4305	0.9575	0.1541	64.20
2	51	0.3942	0.7729	0.1321	66.48
3	40	0.4054	1.0956	0.0948	76.61
4	49	0.4514	1.0031	0.1438	68.14
5	59	0.5843	0.8468	0.2041	65.06
6	59	0.4984	0.7743	0.1341	73.09
7	64	0.5431	0.8485	0.1541	71.62
8	54	0.5779	0.8850	0.1594	72.41
9	60	1.1893	0.3441	0.2045	82.80
10	55	1.1950	0.3421	0.0701	94.13
Average $\bar{c}$	54.0	0.6269	0.7869	0.1451	73.45
Standard Error	± 2.22	± 0.0965	± 0.0804	± 0.0132	± 3.09

Table 92

Diet C

Rat No.	Body wt. (g)	Wt. of pancreas (g)	Wt. of pancreas/ 100g. rat (g)	pancreas dry wt. (g)	Moisture %
1	67	0.4134	0.6170	0.1213	70.65
2	80	0.3158	0.3947	0.1508	52.24
3	93	0.4055	0.4360	0.1684	58.47
4	98	0.4105	0.4188	0.1752	57.32
5	114	0.4360	0.3824	0.1777	59.24
6	97	0.3880	0.4000	0.1624	58.14
7	97	0.3420	0.3525	0.1622	52.51
8	99	0.4260	0.4303	0.1435	66.31
9	118	0.3886	0.3293	0.1305	66.41
10	109	0.4306	0.3950	0.1616	62.47
Average $\bar{c}$ Standard Error	97.2± 4.81	0.3956± 0.1236	0.4156± 0.0246	0.1554± 0.0059	60.38± 1.92

Table 23

Diet D

Rat No.	Body wt. (g)	Wt. of pancreas (g)	Wt. of pancreas/ 100g.rat (g)	pancreas dry wt. (g)	Moisture %
1	83	0.3736	0.4501	0.0650	82.60
2	87	0.4631	0.5323	0.1039	77.56
3	92	0.3615	0.3929	0.1415	60.85
4	102	0.4063	0.3983	0.1200	70.46
5	89	0.3713	0.4171	0.1600	56.90
6	78	0.2566	0.3289	0.1200	53.23
7	62	0.3463	0.5585	0.1127	67.45
8	55	0.2835	0.5154	0.1112	60.77
9	63	0.4133	0.6560	0.0859	79.21
10	68	0.4485	0.6595	0.1602	64.28
Average $\bar{c}$	77.9	0.3724±	0.4909±	0.1180±	67.33±
Standard Error	4.82	0.0207	0.0355	0.0095	3.14

Table 94

Diet E

Rat No.	Body wt. (g.)	Wt. of pancreas (g)	Wt of pancreas/ 100g.rat (g)	pancreas dry wt. (g)	Moisture %
1	76	0.2334	0.3071	0.1834	21.41
2	75	0.2282	0.3042	0.0708	68.97
3	88	0.3292	0.3740	0.1539	53.25
4	95	0.3976	0.4185	0.1348	66.09
5	83	0.2892	0.3784	0.1131	60.89
6	83	0.4380	0.5277	0.1199	72.61
7	77	0.2465	0.3201	0.0234	49.94
8	80	0.3164	0.3955	0.1004	68.27
9	82	0.3284	0.4004	0.1091	67.69
10	83	0.4021	0.4844	0.1343	66.60
Average $\bar{c}$ Standard Error	82.2± 1.89	0.3209± 0.0233	0.3880± 0.0235	0.1143± 0.0193	60.62± 2.89

Table 95

Summarised data* on weight of pancreas recorded in respect of groups of rats maintained on diets A, B, C, D and E.

(vide tables 90-94)

Diets	Wt. of rat (g.)	Fresh Wt. of pancreas (g)	Wt. of pancreas/ 100g. rat (g)	Dry wt. pancreas (g)	Moisture %
A	55.4± 2.14	0.2804± 0.0168	0.5094± 0.0246	0.1178± 0.1001	55.61± 5.58
B	54.0± 2.22	0.6269± 0.0965	0.7869± 0.0804	0.1451± 0.0132	73.45± 3.09
C	97.2± 4.81	0.3956± 0.1236	0.4156± 0.0246	0.1554± 0.0059	60.38± 1.92
D	77.9± 4.82	0.3724± 0.0207	0.4909± 0.0355	0.1180± 0.0095	67.33± 3.14
E	82.2± 1.89	0.3209± 0.0233	0.3880± 0.0235	0.1143± 0.0193	60.62± 2.89

* Mean values (10 animals/group) with standard error.

Table 96

Analysis of variance - Pancreatic weights

Source	df.	SS.	MSS.	F.
Between treatments	4	1.0054	0.2513	13.22**
Error	45	0.8557	0.0190	
Total	49	1.8611		

** Significant at 1% level

Critical difference; 0.1024 at 5% level
0.1348 at 1% level

Mean values: A = 0.5094, B = 0.7869, C = 0.4156, D = 0.4909, E = 0.3880.

SECOND SERIES OF EXPERIMENTS

Table 97

Body weight in g. of animals receiving diets containing cowpea and tur dhal, raw and autoclaved, supplemented with methionine and tryptophane.
Diet F

Rat No.	Weeks				
	0	1	2	3	4
1	60.0	64.0	75.0	85.0	111.0
2	60.0	65.0	69.0	74.0	79.0
3	55.0	58.0	61.0	70.0	81.0
4	47.0	50.0	55.0	60.0	70.0
5	53.0	57.0	60.0	67.0	79.0
6	51.0	55.0	60.0	68.0	81.0
7	61.0	70.0	77.0	88.0	100.0
8	50.0	55.0	59.0	63.0	74.0
9	50.0	57.0	62.0	66.0	75.0
10	54.0	58.0	62.0	69.0	76.0
Average $\bar{c}$	54.1	58.9	64.0	71.0	82.6
Standard Error	$\pm$ 1.54	$\pm$ 1.84	$\pm$ 2.28	$\pm$ 2.85	$\pm$ 1.26

Table 98

Diet G

Rat No.	Weeks				
	0	1	2	3	4
1	53.0	66.0	74.0	85.0	95.0
2	55.0	66.0	73.0	88.0	98.0
3	53.0	69.0	76.0	87.0	104.0
4	53.0	65.0	75.0	86.0	102.0
5	51.0	64.0	71.0	79.0	89.0
6	55.0	64.0	75.0	82.0	94.0
7	60.0	73.0	78.0	92.0	103.0
8	53.0	62.0	74.0	86.0	99.0
9	52.0	63.0	69.0	83.0	94.0
10	50.0	62.0	69.0	80.0	93.0
Average $\bar{c}$ Standard Error	53.5± 0.27	65.4± 1.08	73.4± 0.93	84.8± 1.23	97.1± 1.55

Table 99

Diet H

Rat No.	Weeks 0	1	2	3	4
1	56.0	62.0	72.0	92.0	109.0
2	51.0	58.0	63.0	86.0	102.0
3	47.0	51.0	60.0	76.0	92.0
4	48.0	57.0	63.0	77.0	90.0
5	53.0	62.0	70.0	87.0	96.0
6	56.0	74.0	83.0	108.0	114.0
7	50.0	56.0	67.0	90.0	125.0
8	56.0	70.0	86.0	100.0	110.0
9	54.0	63.0	67.0	84.0	92.0
10	49.0	59.0	77.0	90.0	98.0
Average $\bar{c}$ Standard Error	52.0 ± 1.09	61.2 ± 2.12	70.8 ± 2.76	89.0 ± 3.86	102.8 ± 3.61

Table 100

Diet I

Rat No.	Weeks 0	1	2	3	4
1	57.0	73.0	97.0	106.0	112.0
2	55.0	65.0	91.0	111.0	139 .0
3	50.0	59.0	86.0	97.0	120.0
4	44.0	56.0	75.0	86.0	101.0
5	57.0	66.0	90.0	105.0	126.0
6	52.0	71.0	88.0	91.0	119.0
7	59.0	71.0	96.0	112.0	139.0
8	51.0	64.0	73.0	83.0	108.0
9	55.0	65.0	87.0	94.0	104.0
10	69.0	79.0	103.0	111.0	128.0
Average $\bar{c}$ Standard Error.	54.9± 2.08	66.9± 2.15	88.6± 2.94	99.6± 3.43	119.6± 4.27

Table 101

Weight gain, feed consumption, protein efficiency values of animals fed diets F, G, H and I supplemented with methionine and tryptophane.

Diet F

Rat No.	Initial weight (g)	Final weight (g)	Weight gain (g)	Food intake (g)	Protein intake (g)	Protein efficiency value (PEV)
1	60.0	111.0	51.0	194.7	19.5	2.61
2	60.0	79.0	19.0	136.8	13.7	1.37
3	55.0	81.0	26.0	140.6	14.1	1.84
4	47.0	70.0	23.0	122.6	12.3	1.87
5	53.0	79.0	26.0	144.4	14.4	1.81
6	51.0	81.0	30.0	147.3	14.7	2.04
7	61.0	100.0	39.0	171.0	17.1	2.28
8	50.0	74.0	24.0	124.5	12.4	1.92
9	50.0	75.0	25.0	132.5	13.2	1.88
10	54.0	76.0	22.0	129.7	12.9	1.71
Average $\bar{c}$ Standard Error	54.1± 1.52	82.6± 4.09	28.5± 3.03	144.4± 7.11	14.4± 0.71	1.93± 0.10

Table 102

Diet G

Rat No.	Initial weight (g)	Final weight (g)	Weight gain (g)	Food intake (g)	Protein intake (g)	Protein efficiency value (PEV)
1	53.0	95.0	42.0	166.2	16.6	2.53
2	55.0	98.0	43.0	170.5	17.1	2.51
3	53.0	104.0	51.0	195.7	19.6	2.60
4	53.0	102.0	49.0	186.2	18.6	2.63
5	51.0	89.0	38.0	167.6	16.8	2.26
6	55.0	94.0	39.0	172.4	17.2	2.27
7	60.0	103.0	43.0	181.9	18.2	2.36
8	53.0	99.0	46.0	179.5	17.9	2.57
9	52.0	94.0	42.0	163.8	16.4	2.56
10	50.0	93.0	43.0	168.6	16.9	2.54
Average $\bar{c}$ Standard Error	53.5± 0.97	97.1± 1.55	43.6± 1.28	175.2± 3.24	17.5± 0.32	2.48± 0.13

Table 103

Diet H

Rat No.	Initial weight (g)	Final weight (g)	Weight gain (g)	Food intake (g)	Protein intake (g)	Protein efficiency value (PEV)
1	56.0	109.0	53.0	167.7	16.8	3.15
2	51.0	102.0	51.0	157.7	15.8	3.23
3	47.0	92.0	45.0	151.0	15.1	2.98
4	48.0	90.0	42.0	151.5	15.2	2.76
5	53.0	96.0	43.0	160.0	16.0	2.69
6	56.0	114.0	58.0	200.9	20.1	2.88
7	50.0	125.0	75.0	179.5	17.9	4.19
8	56.0	110.0	54.0	178.6	17.9	3.02
9	54.0	92.0	38.0	144.8	14.5	2.62
10	49.0	98.0	49.0	168.6	16.9	2.90
Average $\bar{c}$ Standard Error	52.0± 1.09	102.8± 3.61	50.8± 0.33	166.0± 5.33	16.6± 0.53	3.04± 0.14

Table 104

Diet I

Rat No.	Initial weight (g)	Final weight (g)	Weight gain (g)	Food intake (g)	Protein intake (g)	Protein efficiency value (PEV)
1	57.0	112.0	55.0	166.3	16.6	3.31
2	55.0	139.0	84.0	162.9	16.3	5.15
3	50.0	120.0	70.0	143.9	14.4	4.86
4	44.0	101.0	57.0	142.5	14.2	4.01
5	57.0	126.0	69.0	165.3	16.5	4.18
6	52.0	119.0	67.0	155.3	15.5	4.32
7	59.0	139.0	80.0	182.3	18.2	4.39
8	51.0	108.0	57.0	151.0	15.1	3.77
9	55.0	104.0	49.0	131.0	13.1	3.74
10	69.0	128.0	59.0	190.0	19.0	3.11
Average $\bar{c}$	54.9±	119.6±	64.7±	159.0±	15.9±	4.08±
Standard Error	2.08	4.27	3.57	5.74	0.81	0.20

Table 105

Nitrogen balance studies.

Diet F

Rat No.	Body weight g.	Body surface cm^2	Nitrogen intake (4 days) mg.	N. Excretion (4 days)			Nitrogen balance mg./day	Nitrogen balance $mg_2/100$ cm^2 body surface	Percent nitrogen retention
				Urinary mg.	Faecal mg.	Total mg.			
1	111.0	210.4	577.6	234.4	66.8	301.2	69.1	32.8	47.8
2	79.0	172.5	304.0	169.5	48.9	218.4	21.4	12.4	28.1
3	81.0	175.2	379.0	195.5	60.6	256.1	30.7	17.5	32.4
4	70.0	160.4	356.8	206.1	35.5	141.6	53.8	33.5	60.3
5	79.0	172.5	364.8	126.5	66.9	193.4	38.8	22.5	42.0
6	81.0	175.2	372.8	154.2	53.2	207.4	41.3	23.6	44.4
7	100.0	198.7	508.8	147.8	101.4	249.2	64.9	32.6	51.0
8	74.0	165.9	334.4	150.7	28.8	179.5	38.7	23.3	46.3
9	75.0	167.2	321.0	112.0	88.9	200.9	30.0	17.9	37.4
10	76.0	168.6	342.4	147.5	75.8	233.3	29.8	17.7	34.8
Average $\bar{c}$ Standard Error	82.6± 1.26	176.7± 4.95	386.2± 27.66	164.4± 11.86	62.7± 7.12	217.1± 15.73	41.8± 5.02	23.3± 2.39	42.4± 3.04

Table 106

Diet G

Rat No.	Body weight g.	Body surface cm^2	Nitrogen intake (4 days) mg.	N. Excretion (4 days)			Nitrogen balance mg./day	N. balance $mg_2/100$ cm^2 body surface	Percent nitrogen retention
				Urinary mg.	Faecal mg.	Total mg.			
1.	95.0	192.7	440.0	154.4	92.4	246.8	48.3	25.1	43.9
2	98.0	196.3	427.0	135.2	74.7	209.9	54.3	27.7	50.8
3	104.0	203.4	456.0	118.4	65.3	183.7	68.1	33.5	59.9
4	102.0	201.1	384.0	129.6	33.8	163.4	55.1	27.4	57.4
5	89.0	185.3	336.0	171.7	50.4	221.1	28.7	15.5	34.2
6	94.0	191.4	344.0	124.6	88.4	213.0	33.0	17.2	38.1
7	103.0	202.2	400.0	140.4	64.5	204.9	48.8	24.1	48.8
8	99.0	197.5	432.0	118.5	54.3	172.8	64.8	32.8	60.6
9	94.0	191.4	368.0	152.0	34.8	186.8	45.3	23.7	49.2
10	93.0	190.3	368.0	194.0	78.5	272.5	23.9	12.5	25.9
Average $\bar{c}$ Standard Error	97.1 $\pm$ 1.55	195.2 $\pm$ 1.87	395.5 $\pm$ 13.26	143.9 $\pm$ 7.76	63.7 $\pm$ 6.47	207.5 $\pm$ 10.94	47.0 $\pm$ 4.65	23.9 $\pm$ 2.22	46.9 $\pm$ 3.62

Table 107

Diet H

Rat No.	Body weight g.	Body surface cm^2	Nitrogen intake (4 days) mg.	N.Excretion (4 days) Urinary mg.	Faecal mg.	Total mg.	Nitrogen balance mg./day	N. balance mg_2/100 cm^2 body surface	Percent nitrogen retention
1	109.0	209.2	608.0	144.9	162.5	307.4	75.1	35.9	49.4
2	102.0	201.1	480.0	124.1	37.5	161.6	79.6	39.6	66.3
3	92.0	189.0	464.0	118.4	54.3	172.7	72.8	38.5	62.8
4	90.0	186.5	416.0	113.8	74.5	188.3	56.9	30.5	54.7
5	96.0	193.9	400.0	163.8	53.2	217.0	45.7	23.6	45.7
6	114.0	211.9	416.0	119.4	44.4	163.8	63.0	29.7	60.6
7	125.0	227.2	640.0	162.8	63.4	226.2	103.4	45.5	64.6
8	110.0	210.4	592.0	118.4	102.5	220.9	92.8	44.1	62.7
9	92.0	189.0	480.0	182.3	41.7	224.0	64.0	33.9	53.3
10	98.0	196.3	480.0	125.0	47.9	172.9	76.8	39.1	63.9
Average $\bar{o}$ Standard Error	102.8± 3.61	201.4± 4.12	497.6± 27.13	137.3± 7.71	68.2± 5.95	205.5± 13.99	73.0± 5.34	36.0± 2.14	58.4± 2.25

Table 108

Diet I

Rat No.	Body weight g.	Body surface cm^2	Nitrogen intake (4 days) mg.	N. Excretion (4 days) Urinary mg.	Faecal mg.	Total mg.	Nitrogen balance mg./day	N. balance mg_2/100 cm^2 body surface.	Percent nitrogen retnetion
1	112.0	212.7	456.0	168.0	48.5	216.5	59.9	28.2	52.5
2	139.0	242.2	504.0	125.1	35.4	160.5	85.9	35.5	68.1
3	120.0	221.7	480.0	135.5	23.4	158.9	80.3	36.2	66.9
4	101.0	199.9	432.0	124.6	27.6	152.2	69.9	34.9	64.8
5	126.0	228.3	608.0	171.5	102.4	273.9	83.5	36.6	54.9
6	119.0	220.6	536.0	134.9	94.4	229.3	76.7	34.8	57.2
7	139.0	242.2	544.0	105.8	27.7	133.5	102.6	42.4	75.4
8	108.0	208.1	432.0	128.1	33.8	161.9	67.5	32.4	62.5
9	104.0	203.4	480.0	95.8	47.5	143.3	84.2	41.4	70.1
10	128.0	230.4	384.0	120.5	58.3	178.8	51.3	22.3	53.4
Average ± Standard Error	119.6± 4.27	220.9± 4.75	485.6± 20.62	130.9± 7.54	49.9± 8.80	180.9± 14.15	76.2± 4.63	34.5± 1.86	62.6± 2.47

Table 109

Digestibility coefficients of dry matter, protein, carbohydrate and fat in the diets containing raw and autoclaved cowpea and tur dhal, supplemented with methionine and tryptophane. (Diets F, G, H and I)

Diet F

Rat No.	Dry matter	Protein	Carbohydrate	Fat
1	87.2	88.4	93.1	94.1
2	90.0	83.9	94.5	93.1
3	82.2	84.0	96.7	92.6
4	88.2	90.0	98.1	90.8
5	87.3	81.7	95.4	91.0
6	94.3	85.7	93.8	95.4
7	89.3	80.1	96.4	93.2
8	87.6	91.4	98.4	90.1
9	86.3	72.3	89.4	89.9
10	87.1	77.9	91.2	91.3
Average $\bar{c}$	87.9±	83.5±	94.7±	92.1±
Standard Error	0.97	1.84	0.92	0.57

Table 110

Diet G

Rat No.	Dry matter	Protein	Carbohydrate	Fat
1	91.2	79.0	92.8	90.3
2	90.8	82.5	90.5	91.2
3	90.8	85.7	91.3	89.9
4	92.3	91.2	95.4	93.3
5	94.9	85.0	96.5	96.8
6	86.0	74.3	93.1	95.4
7	90.3	83.9	96.1	93.1
8	90.1	87.4	93.1	88.4
9	92.2	90.5	89.9	89.7
10	85.9	78.7	88.8	95.1
Average $\bar{c}$	90.4±	83.8±	92.7±	92.3±
Standard Error	0.87	2.26	0.84	0.89

Table 111

Diet H

Rat No.	Dry matter	Protein	Carbohydrate	Fat
1	95.2	73.3	96.8	93.1
2	94.4	92.2	97.1	93.1
3	94.7	88.3	89.9	90.6
4	94.5	82.1	92.5	90.8
5	94.1	86.7	93.1	89.6
6	93.5	89.3	92.0	85.3
7	94.3	90.1	90.1	91.4
8	94.6	82.7	95.4	93.4
9	93.4	91.3	93.2	91.8
10	94.5	90.0	89.1	95.4
Average $\bar{c}$ Standard Error	94.3± 0.17	86.6± 1.82	92.9± 0.89	91.6± 0.93

Table 112

Diet I

Rat No.	Dry matter	Protein	Carbohydrate	Fat
1	95.1	89.4	94.1	90.1
2	94.7	92.9	93.2	92.2
3	94.5	95.1	90.7	89.1
4	95.9	93.6	93.4	92.3
5	96.2	83.1	92.1	94.1
6	95.1	82.4	88.9	90.3
7	95.4	94.9	91.5	90.8
8	95.1	92.2	93.6	90.7
9	95.6	90.1	92.6	93.6
10	94.5	84.8	98.4	95.1
Average $\bar{c}$ Standard Error	95.2 ± 0.16	89.8 ± 1.52	92.8 ± 0.78	91.8 ± 0.62

Table 113

Summarised data* on body weights in g. recorded in respect of groups of rats maintained on diets F, G, H and I, supplemented with methionine and tryptophane.

(Vide Tables 97 to 100)

Diets	No.of animals	Food intake	Weeks 0	1	2	3	4
F	10	144.4± 7.11	54.1± 1.52	58.9± 1.84	64.0± 2.28	71.0± 2.85	82.6± 1.26
G	10	175.2± 3.24	53.5± 0.97	65.4± 1.08	73.4± 0.93	84.8± 1.23	97.1± 1.55
H	10	166.0± 5.33	52.0± 1.09	61.2± 2.13	70.8± 2.76	89.0± 3.86	102.8± 3.61
I	10	159.0± 5.74	54.9± 2.08	66.9± 2.15	88.6± 2.94	99.6± 3.43	119.6± 4.27

* Mean values (10 animals/group) with standard error.

Table 114

Summarised data* on body weight gain feed consumption and protein efficiency values, recorded in respect of groups of rats maintained on diets F, G, H and I

(Vide Tables 101 to 104)

Diets	No. of animals	Body weight		Weight gain (g.)	Food intake (g.)	Protein intake (g.)	Protein efficiency ratio
		Initial (g.)	Final (g.)				
F	10	54.1± 1.52	82.6± 1.26	28.5± 3.03	144.4± 7.11	14.4± 0.71	1.93± 0.10
G	10	53.5± 0.27	97.1± 1.55	43.6± 1.28	175.2± 3.24	17.5± 0.32	2.48± 0.13
H	10	52.0± 1.09	102.8± 3.61	50.8± 0.33	166.0± 5.33	16.6± 0.53	3.04± 0.14
I	10	54.9± 2.08	119.6± 4.27	64.7± 3.57	159.0± 5.74	15.9± 0.81	4.08± 0.20

* Mean values (10 animals/group) with standard error.

Table 115

Summarised data * on nitrogen retention recorded in respect of groups of rats maintained on diets F, G, H, and I supplemented with methionine and tryptophane

(Vide Tables 105 to 108)

Diets	Weight in(g.)	Body surface cm^2	Nitrogen intake (4 days) in(mg)	Nitrogen Excretion(4 days)			Nitrogen balance mg./day	Nitrogen balance mg./100 cm^2 body surface	Percent Nitrogen retention
				Uninary mg.	Faecal mg.	Total mg.			
F	82.6± 1.26	176.7± 4.95	386.2± 27.66	164.4± 11.86	62.7± 7.12	217.1± 15.73	41.8± 5.02	23.3± 2.39	42.4± 3.04
G	97.1± 1.55	195.2± 1.87	395.5± 13.26	143.9± 7.76	63.7± 6.47	207.5± 10.94	47.0± 4.65	23.9± 2.22	46.9± 3.62
H	102.8± 3.61	201.4± 4.12	497.6± 27.13	137.3± 7.71	68.2± 5.95	205.5± 13.99	73.0± 5.34	36.0± 2.14	58.4± 2.25
I	119.6± 4.27	220.9± 4.75	485.6± 20.62	130.9± 7.54	49.9± 8.80	180.8± 14.15	76.2± 4.63	34.5± 1.86	62.6± 2.47

* Mean values (10 animals/group) with standard error.

Table 116

Summarised data on digestibility coefficient recorded in respect of rats fed diets containing raw and autoclaved cowpea and tur dhal, supplemented with methionine and tryptophane

(Vide Tables 109 to 112)

Diets	Dry matter	Protein	Carbohydrate	Fat
F	87.9±0.97	83.5±1.84	97.4±0.92	92.1±0.57
G	90.4±0.87	83.8±2.26	92.7±0.84	92.3±0.89
H	94.3±0.17	86.6±1.82	92.9±0.89	91.6±0.93
I	95.2±0.16	89.8±1.52	92.8±0.78	91.8±0.62

Table 117

Analysis of variance--Body weight gain in g.

Source	df.	SS.	MSS.	F.
Between treatments	4	6887.0	1721.75	13.09*
Error	45	5015.0	131.44	
Total	49	11902.0		

* Significant at 1% level

Critical difference:
8.42 at 5% level
11.09 at 1% level

Mean values: F = 28.5, G = 43.6, H = 50.8, I = 64.7, C = 43.9

Table 118

Analysis of variance--Protein efficiency values

Source	df.	SS.	MSS.	F.
Between treatments	4	26.6894	6.6723	24.93**
Error	45	12.0433	0.2676	
Total	49	38.7327		

** Significant at 1% level

Critical difference:

0.41 at 5% level
0.54 at 1% level

Mean values: F = 1.93, G = 2.48, H = 3.04, I = 4.08, C = 2.47

Table 119

Analysis of variance--per cent Nitrogen retention

Source	df.	SS.	MSS.	F
Between treatments	4	8592.21	2148.05	44.68**
Error	45	2163.24	48.07	
Total	49	10755.45		

** Significant at 1% level

Critical difference:

7.23 at 5% level
9.53 at 1% level

Mean values:

F = 42.4, G = 46.9, H = 58.4, I = 62.6, C = 79.7

Table 120

Analysis of variance--Digestibility coefficient of Protein

Source	df.	SS.	MSS.	F.
Between treatments	4	539.91	134.98	4.46**
Error	45	1360.69	30.24	
Total	49	1900.60		

** Significant at 1% level

Critical difference:

5.01 at 5% level
6.59 at 1% level

Mean values:

F = 83.5, G = 83.8, H = 86.6, I = 89.8, C = 92.9

Table 121

Analysis of variance--Digestibility coefficient of carbohydrate

Source	df.	SS.	MSS.	F.
Between treatments	4	30.34	7.58	1.06
Error	45	320.80	7.13	
Total	49	351.14		

Not significant

Table 122

Analysis of variance--Digestibility coefficient of fat

Source	df.	SS.	MSS.	F.
Between treatments	4	2.99	0.74	0.0001
Error	45	2071.39	46.03	
Total	49	2074.38		

Not significant

Table 123

Red blood cell concentration of animals receiving diets F, G, H and I
Diet F—R.B.C. in millions/mm^3

Rat No.	Weeks				
	0	1	2	3	4
1	6.26	7.53	7.76	7.09	8.49
2	7.64	7.79	7.68	8.15	6.78
3	7.56	7.78	7.71	7.69	8.26
4	7.09	7.66	7.50	7.32	7.18
5	7.71	7.94	7.55	7.79	8.17
6	7.41	7.33	8.06	7.42	7.72
7	7.01	7.12	7.62	7.65	7.92
8	7.60	7.56	7.66	7.45	7.97
9	7.34	7.80	7.54	7.71	7.52
10	7.21	7.41	7.56	7.98	7.37
Average $\bar{c}$ Standard Error	7.28± 0.13	7,59± 0.08	7.66± 0.05	7.62± 0.09	7.73± 0.16

Table 124

(R.B.C. in millions/mm^3)

Diet G

Rat No.	Weeks				
	0	1	2	3	4
1	6.90	7.70	7.78	7.94	8.04
2	7.09	7.21	8.21	8.01	8.02
3	7.02	7.50	7.51	8.35	8.37
4	6.92	7.02	7.61	7.94	8.05
5	7.35	7.44	7.24	7.59	7.62
6	6.55	7.64	7.80	7.83	8.09
7	6.71	6.85	7.17	7.90	8.01
8	6.83	7.34	7.55	8.04	8.08
9	7.47	7.56	7.60	7.73	7.96
10	6.81	6.91	7.10	7.43	7.55
Average $\bar{c}$	6.96±	7.32±	7.56±	7.88±	7.98±
Standard Error	0.08	0.09	0.16	0.08	0.07

Table 125

(R.B.C. in millions/mm^3)

Diet H

Rat No.	Weeks				
	0	1	2	3	4
1	7.43	7.73	7.98	7.88	7.92
2	6.48	7.47	7.34	7.49	7.54
3	6.09	6.78	7.19	7.94	7.90
4	7.32	7.74	7.75	7.81	7.89
5	7.64	7.33	7.34	7.92	7.88
6	6.88	7.38	7.67	7.82	7.94
7	6.54	6.60	7.64	8.14	8.04
8	7.21	7.30	7.68	7.92	7.87
9	7.01	7.24	7.48	7.64	7.77
10	7.54	7.04	7.55	7.60	7.84
Average $\bar{c}$	7.14±	7.26±	7.56±	7.82±	7.86±
Standard Error	0.16	0.11	0.07	0.06	0.04

Table 126

(R.B.C. in millions/mm^3)

Diet I

Rat No.	Weeks				
	0	1	2	3	4
1	7.45	7.54	7.73	7.82	7.91
2	7.32	7.44	7.96	7.97	7.92
3	7.01	7.12	7.91	7.99	8.04
4	7.41	7.09	8.22	8.02	8.21
5	7.54	7.62	8.18	8.21	8.22
6	7.84	7.94	7.60	8.41	8.52
7	7.54	7.78	7.52	7.82	8.22
8	7.68	7.73	7.81	7.91	8.04
9	7.02	6.90	7.04	7.65	7.95
10	7.45	7.62	8.33	8.42	6.51
Average $\bar{c}$	7.43±	7.48±	7.83±	8.02±	8.15±
Standard Error	0.08	0.11	0.12	0.08	0.07

Table 127

Haemoglobin concentration of animals receiving diets F, G, H and I

(Haemoglobin in g./100 ml.)

Diet F

Rat No.	Weeks				
	0	1	2	3	4
1	13.2	13.9	14.7	15.3	15.4
2	13.7	13.7	14.5	13.9	14.5
3	15.0	15.0	15.0	15.3	15.5
4	14.5	14.8	14.8	14.5	14.6
5	14.3	14.8	14.8	14.8	14.8
6	13.9	14.7	14.8	14.8	14.8
7	14.4	14.8	14.6	15.1	15.2
8	14.3	14.3	14.3	14.5	14.9
9	14.2	14.5	14.6	14.7	15.0
10	13.9	14.5	14.6	14.8	14.8
Average $\bar{c}$	14.1	14.5	14.7	14.8	14.9
Standard Error	± 0.15	± 0.13	± 0.06	± 0.13	± 0.07

Table 128

(Haemoglobin in g./100 ml.)

Diet G

Rat No.	Weeks				
	0	1	2	3	4
1	14.0	14.5	14.7	14.7	14.8
2	13.7	14.0	14.2	14.7	14.4
3.	14.2	14.2	14.7	14.5	14.8
4	14.4	14.7	14.8	14.8	15.4
5	14.1	14.5	14.3	14.5	15.0
6	13.6	14.7	13.6	14.7	15.0
7	14.5	15.0	15.2	15.3	15.4
8	14.0	14.5	14.3	14.2	14.5
9	14.0	14.5	15.1	15.3	15.5
10	14.2	14.4	14.6	14.8	15.0
Average $\bar{c}$ Standard Error	14.1± 0.08	14.5± 0.08	14.5± 0.14	14.7± 0.11	15.0± 0.53

Table 129

(Haemoglobin in g./100 ml.)

Diet H

Rat No.	Weeks				
	0	1	2	3	4
1	13.5	13,5	14,5	15.2	15.5
2	14.5	14.5	14.6	14.7	15.0
3	13.8	14.0	14.5	15.5	15.7
4	13.2	14.5	14.5	15.3	15.4
5	14.1	14.5	15.5	15.4	15.6
6	14.2	14.0	14.5	15.0	15.2
7	14.2	14.5	14.5	14.2	14.9
8	13.8	14.5	14.5	15.0	15.2
9	15.0	15.0	15.0	15.0	15.4
10	14.2	14.0	15.0	15.5	15.0
Average $\bar{c}$ Standard Error	14.0± 0.16	14.3± 0.13	14.7± 0.22	15.1± 0.12	15.3± 0.08

Table 130

(Haemoglobin in g./100 ml.)

Diet I

Rat No.	Weeks				
	0	1	2	3	4
1	14.5	14.5	14.6	15.0	15.4
2	14.7	15.0	15.1	15.0	15.0
3	13.7	14.0	14.4	15.0	15.2
4	14.5	14.0	14.4	15.4	15.4
5	14.2	15.0	15.9	15.6	15.5
6	14.2	15.4	15.5	15.4	15.5
7	14.3	14.5	14.7	14.8	15.0
8	14.8	15.5	15.0	15.4	15.8
9	14.3	14.2	14.5	14.8	15.1
10	14.5	15.0	15.1	15.7	15.6
Average c with standard Error	14.4± 0.09	14.7± 0.17	14.9± 0.13	15.2± 0.14	15.3± 0.08

Table 131

Plasma protein concentration of animals maintained on diets F, G, H and I
(Values in g./100 ml.)

Rat No.	Diets F	G	H	I
1	6.5	6.5	6.8	6.5
2	6.8	6.3	6.5	6.3
3	6.5	5.9	6.4	6.8
4	7.1	6.3	6.8	7.1
5	7.0	6.2	7.1	6.9
6	6.7	6.4	6.9	6.4
7	6.8	5.9	6.5	7.0
8	6.1	6.8	6.3	6.5
9	6.7	6.2	7.0	6.8
10	6.6	6.7	7.0	6.5
Average $\bar{c}$	6.7	6.3±	6.7±	6.7±
Standard Error	0.08	0.10	0.09	0.08

Table 132

*Effect of feeding cowpea and tur dhal diets at 10% protein level on nitrogen basis, raw and autoclaved, supplemented with methionine and tryptophane (Diets F, G, H and I) on red blood cell concentration.

(R.B.C. in millions/mm^3)

Diets	No.of animals	Weeks				
		0	1	2	3	4
F	10	7.28± 0.13	7.59± 0.08	7.66± 0.05	7.62± 0.09	7.73± 0.16
G	10	6.96± 0.08	7.32± 0.09	0.56± 0.16	7.88± 0.08	7.98± 0.98
H	10	7.14± 0.16	7.26± 0.11	7.56± 0.07	7.82± 0.06	7.86± 0.04
I	10	7.43± 0.08	7.48± 0.11	7.83± 0.12	8.02± 0.08	8.15± 0.07

* Mean values (10 animals/group) with standard error.

Table 133

Summarised data* on plasma protein and haemoglobin concentration of animals maintained on diets F, G, H and I (Vide Tables 127 to 131)

(Values in g./100 ml.)

Diets	No.of animals	Plasma protein	Weeks				
			0	1	2	3	4
F	10	6.7± 0.08	14.1± 0.15	14.5± 0.13	14.7± 0.06	14.8± 0.13	14.9± 0.07
G	10	6.3± 0.10	14.1± 0.08	14.5± 0.08	14.5± 0.14	14.7± 0.11	15.0± 0.53
H	10	6.7± 0.09	14.0± 0.16	14.3± 0.13	14.7± 0.22	15.1± 0.12	15.3± 0.08
I	10	6.7± 0.08	14.4± 0.09	14.7± 0.17	14.9± 0.13	15.2± 0.14	15.3± 0.08

Table 134

Analysis of variance--Red blood cells

Source	df.	SS.	MSS.	F.
Between treatments	4	1.0394	0.2598	2.28
Error	45	5.1286	0.1139	
Total	49	6.1680		

Not significant

Table 135

Analysis of variance--Haemoglobin concentration

(g./100 ml.)

Source	df.	SS.	MSS.	F.
Between treatments	4	4.19	1.048	9.17**
Error	45	5.14	0.114	
Total	49	9.33		

** Significant at 1% level.

Critical difference:

0.32 at 5% level
0.42 at 1% level

Mean values:

F = 14.09, G = 15.0, H = 15.3, I = 15.3, C = 14.5.

Table 136

Analysis of variance--Plasma protein

(g./100 ml.)

Source	df.	SS.	MSS.	F.
Between treatments	4	1.27	0.3175	6.0**
Error	45	2.38	0.0528	
Total	49	3.65		

** Significant at 1% level

Critical difference:

0.34 at 5% level
0.45 at 1% level

Mean values:

F = 6.7, G = 6.3, H = 6.7, I = 6.7, C = 6.5.

Table 137

Glutamic-Oxalo acetic transaminase and Glutamic-Pyruvic transaminase levels in in serum and liver of animals maintained on diets F,G,H and I.

Diet F

Rat No.	Glutamic - Oxalo acetic transaminase		Glutamic-Pyruvic transaminase	
	Serum/units/ml.	Liver/units/g.liver	Serum/units/ml.	Liver/units/g.liver
1	98.0	325.0	215.0	588.0
2	100.0	465.0	118.0	612.0
3	112.0	318.0	167.0	608.0
4	120.0	374.0	201.0	514.0
5	130.0	492.0	198.0	438.0
6	124.0	594.0	189.0	475.0
Average $\bar{c}$	114.0±	428.0±	184.7±	539.2±
Standard Error	17.16	44.21	13.94	30.23

Table 138

Diet G

Rat No.	Glutamic - Oxalo acetic transaminase		Glutamic - Pyruvic transaminase	
	Serum units/ml.	Liver units/g.	Serum units/ml.	Liver units/g.
1	123.0	452.0	187.0	458.0
2	142.0	368.0	213.0	584.0
3	135.0	546.0	219.0	612.0
4	130.0	340.0	192.0	574.0
5	110.0	218.0	199.0	535.0
6	104.0	415.0	184.0	435.0
Average $\bar{c}$	124.0±	238.9±	199.0±	533.0±
Standard Error	5.99	45.22	5.81	29.30

Table 139

Diet H

Rat No.	Glutamic-Oxalo acetic transaminase		Glutamic-Pyruvic transaminase	
	Serum units/ml.	Liver units/g.	Serum units/ml.	Liver units/g.
1	112.0	495.0	208.0	648.0
2	109.0	358.0	192.0	535.0
3	130.0	554.0	189.0	438.0
4	141.0	467.0	218.0	640.0
5	128.0	514.0	201.0	535.0
6	105.0	618.0	194.0	528.0
Average $\bar{c}$	120.8±	501.0±	200.3±	554.0±
Standard Error	5.81	11.27	4.51	32.18

Table 140

Diet I

Rat No.	Glutamic-Oxaloacetic transaminase		Glutamic-Pyruvic transaminase	
	Serum units/ml.	Liver units/g.	Serum units/ml.	Liver units/g.
1	110.0	463.0	215.0	645.0
2	108.0	592.0	206.0	538.0
3	112.0	452.0	199.0	687.0
4	125.0	464.0	208.0	742.0
5	140.0	388.0	187.0	518.0
6	120.0	412.0	193.0	438.0
Average $\bar{c}$	119.2±	461.8±	201.3±	594.7±
Standard Error	4.93	28.85	4.22	47.04

Table 141

Data on liver glycogen content of animals maintained on diets F, G, H and I.

Rat No.	Diets F Liver	G Liver	H Liver	I Liver
1	2.57	2.87	2.58	2.26
2	2.21	2.16	2.67	3.77
3	2.52	2.13	2.83	2.12
4	2.72	2.01	2.82	2.60
5	2.06	2.16	2.50	2.65
6	2.62	2.51	2.84	2.52
Average $\bar{c}$	2.45±	2.31±	2.71±	2.65±
Standard Error	0.10	0.13	0.01	0.06

Table 142

Summarised data* on Glutamic-Oxalo acetic transaminase, Glutamic-Pyruvic transaminase levels in serum and liver of rats fed diets containing cowpea and tur dhal at 10% protein level, supplemented with methionine and tryptophane. (Diets F, G, H and I)

Diets	No. of animals.	Glutamic-Oxalo acetic transaminase		Glutamic-Pyruvic transaminase	
		Serum units/ml.	Liver units/g.	Serum units/ml.	Liver units/g.
F	6	114.0± 17.16	428.0± 44.21	184.7± 13.97	539.2± 30.23
G	6	124.0± 5.99	238.9± 45.22	199.0± 5.81	533.0± 29.30
H	6	120.8± 5.81	510.0± 11.27	200.3± 4.51	544.0± 32.18
I	6	119.2± 4.93	416.8± 28.85	201.3± 4.22	594.7± 47.04

*Mean values (6 animals/group) with standard error.

Table 143

Summarised data* on glycogen content of liver recorded in respect of animals maintained on diets F, G, H and I.
(Values in g./100 g. tissue)

Diets	No. of animals	Body weight of animals (g.)	Liver glycogen
F	6	82.6± 1.26	2.45± 0.10
G	6	97.1± 1.55	2.31± 0.13
H	6	102.8± 3.61	2.71± 0.01
I	6	119.6± 4.27	2.65± 0.06

* Mean values (6 animals/group) with standard error.

Table 144

Analysis of variance-Glutamic-Oxalo acetic transaminase in Serum (units /ml.)

Source	df.	SS.	MSS.	F.
Between feeds	4	320.9	80.225	0.39
Error	25	5057.0	202.208	
Total	29	5377.9		

Not significant

Table 145

Analysis of variance-Glutamic-Oxalo acetic transaminase in liver (units/g)

Source	df	SS.	MSS.	F.
Between feeds	4	40604.0	10151.0	1.26
Error	25	201390.0	8055.6	
Total	29	241994.0		

Not significant

Table 146

Analysis of variance-Glutamic-Pyruvic transaminase in serum (units/ml).

Source	df	SS.	MSS.	F.
Between feeds	4	1110.2	277.55	2.08
Error	25	3437.7	137.51	
Total	29	4547.9		

Not significant

Table 147

Analysis of variance-Glutamic-Pyruvic transaminase in liver (units/g)

Source	df.	SS.	MSS.	F.
Between feeds	4	954.0	238.5	0.294
Error	25	202630.0	8105.2	
Total	29	203584.0		

Not significant

Table 148

Analysis of variance-liver glycogen

Source	df.	SS.	MSS.	F.
Between feeds	4	0.7674	0.1918	1.55
Error	25	3.0965	0.1239	
Total	29	3.8639		

Not significant

Table 149

Liver protein and liver fat contents of animals maintained on Diets F, G, H and I.

Diet F

Rat No.	Body wt.	Fresh wt. of Liver		Total Lipids		Total Protein	
		wt. in g.	% of body wt.	% of Fresh wt	mg/100g rat	% of Fresh wt	mg/100g rat
1	111.0	7.66	6.96	2.84	197.8	15.14	1044.8
2	79.0	5.62	7.11	3.12	221.9	13.38	951.8
3	81.0	6.38	7.88	2.58	203.2	16.45	1295.6
4	70.0	4.29	6.13	3.44	210.8	15.15	928.5
5	79.0	5.69	7.20	4.04	290.9	17.01	1225.1
6	81.0	3.14	3.88	2.85	110.4	14.03	543.9
7	100.0	6.11	6.11	3.84	234.6	12.14	741.7
8	74.0	4.80	6.49	5.17	335.3	11.05	716.7
9	75.0	4.02	5.36	4.53	242.8	10.78	577.8
10	76.0	4.23	5.56	2.23	194.1	10.54	586.6
Average $\bar{c}$	82.6±	5.19±	6.29±	3.46±	217.2±	13.57±	861.2±
Standard Error	1.26	0.42	0.36	0.29	26.52	0.75	85.57

Table 150

Diet G

Rat No.	Body wt.	Fresh wt of Liver		Total Lipids		Total Protein	
		wt in g.	% of body wt.	% of Fresh wt.	mg/100g rat	% of Fresh wt	mg/100g rat
1	95.0	3.53	3.71	4.12	137.8	15.78	586.3
2	98.0	3.54	3.61	3.43	123.9	16.43	593.5
3	104.0	4.99	4.79	3.28	157.4	15.83	759.5
4	102.0	3.35	3.28	4.54	149.1	14.55	477.9
5	89.0	3.03	3.40	6.18	210.3	16.04	546.1
6	94.0	4.64	4.63	5.33	263.1	13.88	685.1
7	103.0	6.29	6.11	4.15	253.4	14.55	888.5
8	99.0	5.70	5.76	5.16	297.1	16.84	969.6
9	94.0	5.09	5.41	6.14	332.5	15.75	852.8
10	93.0	5.59	6.01	5.13	308.3	20.14	1210.6
Average $\bar{c}$	97.1±	4.57±	4.67±	4.75±	223.3±	15.98±	756.9±
Standard Error	1.55	0.36	0.35	0.32	24.56	0.54	71.5

Table 151

Diet H

Rat No.	Body wt.	Fresh wt of Liver		Total Lipids		Total Protein	
		wt in g.	% of body wt	% of Fresh wt	mg/100g rat	%of Fresh wt	mg%100g rat
1	109.0	7.43	6.82	4.14	282.2	18.44	1325.1
2	102.0	6.32	6.19	8.15	195.2	15.32	949.2
3	92.0	5.80	6.30	3.05	192.3	16.43	1035.8
4	90.0	5.74	6.38	4.44	283.2	16.85	1074.6
5	96.0	6.84	7.12	4.55	324.2	15.35	1093.7
6	114.0	5.45	4.78	6.84	327.0	14.88	711.4
7	125.0	9.41	7.53	5.15	387.7	14.32	1078.0
8	110.0	8.66	7.87	4.31	339.3	16.82	1324.2
9	92.0	5.34	5.80	4.35	252.5	21.40	1242.1
10	98.0	6.12	6.24	4.59	286.6	15.55	971.1
Average $\bar{c}$ Standard Error	102.8± 3.61	6.71± 0.44	6.53± 0.28	4.46± 0.85	287.0± 19.57	16.54± 0.65	1080.5± 58.96

Table 152

Diet I

Rat No.	Body wt.	Fresh wt of Liver		Total Lipids		Total Proteins	
		wt in g.	% of body wt.	% of Fresh wt	mg/100g rat	% of Fresh wt	mg/100g rat
1	112.0	5.19	4.63	3.01	139.5	24.85	1151.5
2	139.0	6.49	4.67	3.84	179.3	13.14	613.5
3	120.0	6.63	5.52	4.11	227.1	16.84	930.4
4	101.0	4.48	4.43	4.25	188.5	15.45	685.3
5	126.0	8.68	6.89	4.58	315.5	19.43	1338.5
6	119.0	5.83	4.90	5.31	260.1	20.15	987.2
7	139.0	9.42	6.77	8.02	543.5	15.83	1072.8
8	108.0	6.99	6.47	2.01	130.1	16.46	1065.3
9	104.0	5.74	5.32	2.58	142.4	16.85	929.9
10	128.0	6.14	4.29	2.64	126.6	15.04	721.4
Average $\bar{c}$ Standard Error	119.6± 4.27	6.56± 0.47	5.46± 0.11	4.03± 0.55	225.3± 40.43	17.40± 1 .05	949.6± 63.03

Table 153

Summarised data* on liver protein and liver fat contents of animals maintained on Diets F, G, H and I.
(Vide tables 149-152)

Diets	No. of animals	Weight of liver		Total lipids		Total protein	
		Fresh wt. (g.)	% of body (wt.	% of Fresh wt.	mg/100g rat	% of fresh wt.	mg/100g rat
F	10	5.19± 0.42	6.29± 0.36	3.46± 0.29	217.2± 26.52	13.57± 0.75	861.2± 85.57
G	10	4.57± 0.36	4.67± 0.35	4.75± 0.32	223.3± 24.56	15.98± 0.54	756.9± 71.5
H	10	6.71± 0.44	6.53± 0.28	4.46± 0.85	287.0± 19.57	16.54± 0.65	1080.5± 58.96
I	10	6.56± 0.47	5.46± 0.11	4.03± 0.55	225.3± 40.43	17.40± 1.05	949.6± 63.03

* Average values (10 animals/group) with standard error.

Table 154

Analysis of variance-Liver fat percentage on fresh basis.

Source	df.	SS.	MSS.	F.
Between feeds	4	456.6094	114.1523	78.98 **
Error	45	65.0420	1.4454	
Total	49	521.6514		

** significant at 1% level

Critical difference

1.05 at 5% level

1.38 at 1% level

Mean values

F = 3.46 G = 4.75 H = 4.46 I = 4.03 C = 3.77

Table 155

Analysis of variance-Liver protein percentage on fresh basis.

Source	df.	SS.	MSS.	F.
Between feeds	4	112.1555	28.0389	5.45 **
Error	45	231.4127	5.1425	
Total	49	343.5682		

** Significant at 1% level

Critical difference

1.81 at 5% level

2.38 at 1% level

Mean values

F = 13.57 G = 15.98 H = 16.54 I = 17.40 C = 13.90

Table 156

Internal organ weights of animals maintained on diets F, G, H and I.

Diet F

Rat No.	Body wt. g.	Body surface cm^2	Weight of organs in g. per 100 cm^2 body surface				
			Liver	Kidney	Spleen	Heart	Pancreas
1	111	210.4	3.6433	0.5680	0.1356	0.2116	0.1909
2	79	172.5	3.2588	0.5656	0.1411	0.1971	0.2378
3	81	175.2	3.6444	0.5183	0.2500	0.2109	0.2081
4	70	160.4	2.6787	0.4111	0.1299	0.1926	0.2173
5	79	172.5	3.2985	0.4768	0.1571	0.1909	0.2768
6	81	175.2	1.7920	0.4287	0.1268	0.1954	0.2153
7	100	198.7	3.0735	0.5258	0.1685	0.1728	0.2260
8	74	165.9	2.8947	0.5104	0.1445	0.1656	0.2236
9	75	167.2	2.4042	0.4795	0.1485	0.1938	0.2337
10	76	168.6	2.5119	0.4661	0.4157	0.1897	0.2569
Average $\bar{c}$	82.6±	176.7±	2.9200±	0.4950±	0.1548±	0.1920±	0.2286±
Standard Error	4.26	4.95	0.4241	0.0173	0.0105	0.0045	0.0077

Table 157

Diet G

Rat No.	Body wt. (g.)	Body surface cm^2	Weight of organs in g. per 100 cm^2 body surface				
			Liver	Kidney	Spleen	Heart	Pancreas
1	95.0	192.7	1.8333	0.4002	0.1470	0.1556	0.1975
2	98.0	196.3	1.8050	0.3844	0.1426	0.1773	0.1730
3	104.0	203.4	2.4554	0.4021	0.1497	0.1727	0.1757
4	102.0	201.1	1.6671	0.3842	0.1289	0.1393	0.2154
5	89.0	185.3	1.6390	0.4161	0.1429	0.1537	0.2239
6	94.0	191.4	2.4266	0.5433	0.1645	0.1798	0.1534
7	103.0	202.2	3.1118	0.5504	0.1692	0.1915	0.1442
8	99.0	197.5	2.8881	0.5647	0.1623	0.1662	0.1537
9	94.0	191.4	2.6606	0.5787	0.1654	0.1824	0.1362
10	93.0	190.3	2.9381	0.5079	0.1599	0.1887	0.1265
Average $\bar{c}$	97.1±	195.2±	2.3425±	0.4732±	0.1532±	0.1707±	0.1699±
Standard Error	1.55	1.87	0.0566	0.6265	0.0045	0.0054	0.0105

Table 158

Diet H

Rat No.	Body wt. g.	Body surface cm^2	Weight of organ in g. per 100 cm^2 body surface				
			Liver	Kidney	Spleen	Heart	Pancreas
1	109.0	209.2	3.5510	0.5216	0.1549	0.1821	0.1878
2	102.0	201.1	3.1413	0.4987	0.1607	0.1995	0.1699
3	92.0	189.0	3.0695	0.4654	0.1730	0.2072	0.1534
4	90.0	186.5	3.0797	0.4599	0.1829	0.2025	0.1524
5	96.0	193.9	3.5281	0.6157	0.2781	0.2342	0.1949
6	114.0	211.9	2.5721	0.6258	0.1883	0.2195	0.1291
7	125.0	227.2	4.1411	0.5529	0.1750	0.2466	0.1437
8	110.0	210.4	4.1163	0.5295	0.3619	0.2089	0.1494
9	92.0	189.0	3.4146	0.5600	0.2859	0.2414	0.1584
10	98.0	196.3	2.9766	0.4822	0.2478	0.2201	0.1652
Average $\bar{c}$	102.8±	201.4±	3.3592±	0.5312±	0.2208±	0.2162±	0.1604±
Standard Error	3.61	4.12	0.1571	0.2000	0.0224	0.0063	0.0063

Table 159

Diet I

Rat. No.	Body wt. g.	Body surface cm^2	Weight of organs in g. per 100 cm^2 body surface				
			Liver	Kidney	Spleen	Heart	Pancreas
1	112	212.7	2.4436	0.5182	0.2205	0.2174	0.1434
2	139	242.2	2.6792	0.4708	0.1315	0.2135	0.1563
3	120	221.7	2.9906	0.4424	0.1458	0.1808	0.1322
4	101	199.9	2.2397	0.4191	0.1921	0.1985	0.0850
5	126	228.3	3.8038	0.5165	0.1342	0.2047	0.0771
6	119	220.6	2.6419	0.5055	0.1584	0.1846	0.1238
7	139	242.2	3.8874	0.5106	0.1898	0.1841	0.0998
8	108	208.1	3.3614	00.4457	0.2100	0.2059	0.0791
9	104	203.4	3.5028	0.5647	0.1902	0.2391	0.1224
10	128	230.4	3.0012	0.4538	0.1894	0.2010	0.1121
Average $\bar{c}$	119.6	220.9	3.0552	0.4847	0.1762	0.2029	0.1131
Standard Error	± 4.27	± 4.75	± 0.1747	± 0.0141	± 0.0071	± 0.0055	± 0.0089

Table 160

Summarised data* on internal organ weights recorded in respect of rats maintained on diets F, G, H and I.

(Vide Tables 156-159)

Diets	Body wt. (g.)	Body surface cm^2	Weights of organs in g. per 100 cm^2 body surface				
			Liver	Kidney	Spleen	Heart	Pancreas
F	82.6± 1.26	176.7± 4.95	2.9200± 0.4241	0.4950± 0.0173	0.1548± 0.0105	0.1920± 0.0045	0.2286± 0.0077
G	97.1± 1.55	195.2± 1.87	2.3425± 0.0566	0.4732± 0.6265	0.1532± 0.0045	0.1707± 0.0054	0.1699± 0.0105
H	102.8± 3.61	201.4± 4.12	3.3592± 0.1571	0.5312± 0.2000	0.2208± 0.0224	0.2162± 0.0063	0.1604± 0.0063
I	119.6± 4.27	220.9± 4.75	3.0552± 0.1747	0.4847± 0.0141	0.1762± 0.0071	0.2029± 0.0055	0.1131± 0.0089

* Mean values (10 animals/group) with standard Error.

Table 161

Analysis of variance-weight of spleen in g.

Source	df.	SS.	MSS.	F.
Between feeds	4	0.0544	0.0136	8.00 **
Error	45	0.0777	0.0017	
Total	49	0.1321		

** significant at 1% level.

Critical difference:

0.0334 at 5% level

0.0439 at 1% level

Mean values:

F = 0.1548 G = 0.1532 H = 0.2208 I = 0.1762 C = 0.2319

Table 162

Analysis of variance-weight of liver in g.

Source	df.	SS.	MSS.	F.
Between feeds	4	5.4472	1.3618	4.65**
Erro	45	13.1628	0.2925	
Total	49	18.6100		

** Significant at 1% level.

Critical difference

0.4673 at 5% level

0.6151 at 1% level

Mean values

F = 2.9200 G = 2.3425 H = 3.3592 I = 3.0552 C = 2.7603.

Table 163

Analysis of variance-weight of kidney in g.

Source	df.	SS.	MSS.	F.
Between feeds	4	0.0355	0.0089	2.34*
Error	45	0.1727	0.0038	
Total	49	0.2082		

* Not significant

Critical difference

0.0706 at 5% level

0.0929 at 1% level

Mean values

F = 0.4950 G = 0.4732 H = 0.5312 I = 0.4847 C = 0.4500

Table 164

Analysis of variance-weights of heart in g.

Source	df.	SS.	MSS.	F.
Between feeds	4	0.0221	0.0055	3.56*
Error	45	0.0699	0.0016	
Total	49	0.0920		

* significant at 5% level

Critical difference

0.0322 at 5% level

0.0424 at 1% level

Mean values

F = 0.1920 G = 0.1707 H = 0.2162 I = 0.2029 C = 0.1953.

Table 165

Influence of diets containing cowpea and tur dhal at 10% protein level, (Nx6.25) raw and autoclaved, supplemented with methionine and tryptophane on caecal distension of rats.

Diet F

Rat No.	Body wt.(g)	wt. of caecum with contents (g.)	wt. of caecum with contents/ 100g body wt. (g.)	wt. of caecum without contents (g.)	wt. of caecum without contents/ 100g body wt. (g.)
5	79.0	1.78	2.25	0.23	0.29
6	81.0	0.82	1.01	0.26	0.32
7	100.0	2.06	2.06	0.22	0.21
8	74.0	1.46	1.98	0.19	0.26
9	75.0	1.36	1.82	0.15	0.19
10	76.0	1.48	1.95	0.13	0.17
Average $\bar{c}$	80.8±	1.49±	1.85±	0.19±	0.19±
Standard Error	3.97	0.17	0.17	0.02	0.02

Table 166

Diet G

Rat No.	Body wt.(g)	wt. of caecum with contents (g)	wt. of caecum with contents/ 100g body wt. (g)	wt. of caecum without contents (g)	wt. of caecum without contents/ 100g body wt. (g)
5	89.0	2.73	3.06	0.35	0.39
6	94.0	3.77	4.01	0.26	0.27
7	103.0	8.31	8.07	0.48	0.47
8	99.0	5.03	5.08	0.41	0.42
9	94.0	5.52	5.87	0.36	0.38
10	93.0	4.22	4.54	0.28	0.29
Average $\bar{c}$	95.3±	4.93±	5.11±	0036±	0.37±
Standard Error	2.01	0.78	0.71	0.03	0.03

Table 167

Diet H

Rat No.	Body wt.(g)	wt. of caecum with contents (g)	wt. of caecum with contents/ 100g body wt. (g)	wt. of caecum without contents (g)	wt. of caecum without contents/ 100 g body wt. (g)
1	109.0	1.51	1.39	0.23	0.21
2	102.0	1.42	1.39	0.18	0.18
3	92.0	1.99	2.16	0.18	0.19
4	90.0	1.25	1.39	0.17	0.17
5	96.0	1.55	1.62	0.22	0.23
6	114.0	1.35	1.18	0.15	0.13
Average $\bar{c}$	100.5±	1.51±	1.52±	0.19±	0.19±
Standard Error	3.91	0.14	0.14	0.01	0.01

Table 168

Diet I

Rat No.	Body wt.(g)	wt. of caecum with contents (g.)	wt. of caecum with contents/ 100g body wt. (g.)	wt. of caecum without contents (g.)	wt. of caecum without contents/ 100g body wt. (g.)
5	126.0	2.53	2.01	0.24	0.19
6	119.0	1.71	1.44	0.19	0.17
7	139.0	2.35	1.69	0.24	0.17
8	108.0	2.21	2.05	0.28	0.27
9	104.0	1.77	1.71	0.24	0.23
10	128.0	2.01	1.57	0.21	0.16
Average $\bar{c}$	120.7±	2.09±	1.75±	0.23±	0.20±
Standard Error	5.35	0.13	0.09	0.01	0.02

Table 169

Summarised data on caecal measurements of rats fed diets containing cowpea and turdhal at 10% protein level, raw and autoclaved, supplemented with methionine and trptophane.

Average values with standard error.

Diets	Body wt.(g)	wt. of caecum with contents (g)	wt. of caecum with contents/ 100g body wt. (g)	wt. of caecum without contents (g)	wt. of caecum without contents/ 100g body wt. (g)
F	80.8± 3.97	1.49± 0.17	1.85± 0.17	0.19± 0.02	0.19± 0.02
G	95.3± 2.01	4.93± 0.78	5.11± 0.71	0.36± 0.03	0.37± 0.03
H	100.5± 3.91	1.51± 0.11	1.52± 0.14	0.19± 0.01	0.19± 0.01
I	120.7± 5.35	2.09± 0.13	1.75± 0.09	0.23± 0.01	0.20± 0.02

Table 170

Analysis of variance-weight of caecum with contents/100g. body weight

Source	df.	SS.	MSS.	F.
Between feeds	4	63.0512	15.7628	23.21**
Error	25	16.9779	0.6791	
Total	29	80.0291		

** Significant at 1% level.

Critical difference

0.71 at 5% level

0.96 at 1% level

Mean values

F = 1.85 G = 5.11 H = 1.52 I = 1.75 C = 1.12

Table 171

Analysis of variance-weight of caecum without contents/100g. body weight.

Source	df.	SS.	MSS.	F.
Between feeds	4	0.1094	0.0273	5.25**
Error	25	0.1320	0.0052	
Total	29	0.2414		

** Significant at 1% level.

Critical difference

0.0801 at 5% level

0.1083 at 1% level

Mean values

F = 0.19 G = 0.37 H = 0.19 I = 0.20 C = 0.27

Table 172

Weight of pancreas of animals maintained on diets F, G, H and I

Diet F

Rat No.	Body wt. (g.)	Wt. of pancreas (g)	Wt. of pancreas/ 100g. rat (g.)	Pancreas dry wt. (g.)	Moisture %
1	111	0.4016	0.3618	0.1459	63.67
2	79	0.4103	0.5193	0.1325	67.70
3	81	0.3646	0.4501	0.1256	65.55
4	70	0.3485	0.4978	0.1584	54.54
5	79	0.4775	0.6044	0.2009	57.92
6	81	0.3772	0.4656	0.1300	65.53
7	100	0.4502	0.4502	0.1450	67.79
8	74	0.3710	0.5013	0.1134	69.43
9	75	0.3908	0.5210	0.1450	62.89
10	76	0.4331	0.5698	0.1494	65.50
Average $\bar{c}$	82.6±	0.4025±	0.4941±	0.1446±	64.05±
Standard Error	1.26	0.0129	0.0215	0.0075	1.46

Table 173

Diet G

Rat No.	Body wt. (g.)	Wt. of pancreas (g.)	Wt. of pancreas/ 100g. rat (g.)	Pancreas dry wt. (g.)	Moisture %
1	95	0.3806	0.4006	0.1315	65.44
2	98	0.3397	0.3466	0.1650	51.42
3	104	0.3574	0.3437	0.1535	57.05
4	102	0.4331	0.4246	0.0753	82.61
5	89	0.4150	0.4662	0.2089	119.66
6	94	0.2936	0.3123	0.1455	50.44
7	103	0.2915	0.2830	0.1467	49.67
8	99	0.3036	0.3066	0.1456	52.04
9	94	0.2608	0.2774	0.1325	49.19
10	93	0.3415	0.3672	0.1451	57.51
Average $\bar{c}$ Standard Error	97.1 ± 1.55	0.3417 ± 0.0177	0.3528 ± 0.0197	0.1449 ± 0.0114	63.50 ± 7.03

Table 174

Diet H

Rat No.	Body wt. (g.)	wt. of pancreas (g.)	wt. of pancreas/ 100g. rat. (g.)	Pancreas dry wt. (g.)	Moisture %
1	109	0.3929	0.3604	0.0660	83.20
2	102	0.3417	0.3350	0.1085	68.24
3	92	0.2899	0.3151	0.1320	54.46
4	90	0.2842	0.3157	0.1214	57.28
5	96	0.3779	0.3936	0.1693	55.19
6	114	0.2735	0.2399	0.1153	87.84
7	125	0.3266	0.2612	0.1541	52.81
8	110	0.3144	0.2858	0.1431	54.48
9	92	0.2994	0.3254	0.1054	64.79
10	98	0.3243	0.3309	0.1554	52.08
Average $\bar{c}$ Standard Error	102.8± 3.61	0.3225± 0.0122	0.2833± 0.0490	0.1271± 0.0096	63.04± 4.11

Table 175

Diet I

Rat No.	Body wt. (g)	wt. of Pancreas (g.)	wt. of pancreas/ 100g. rat (g.)	Pancreas dry wt. (g.)	Moisture %
1	112	0.3050	0.2723	0.1421	53.40
2	139	0.3780	0.2723	0.1125	70.28
3	120	0.2930	0.2441	0.1541	47.40
4	101	0.1699	0.1603	0.1379	18.83
5	126	0.1761	0.1375	0.1136	35.49
6	119	0.2731	0.2294	0.1500	45.07
7	139	0.2417	0.1738	0.1410	41.66
8	108	0.1559	0.1444	0.0800	48.68
9	104	0.2490	0.2394	0.1450	41.72
10	128	0.2584	0.2019	0.1845	28.59
Average $\bar{c}$	119.6	0.2500	0.2075	0.1361	43.11
Standard Error	$\pm$ 4.27	$\pm$ 0.0218	$\pm$ 0.0511	$\pm$ 0.0089	$\pm$ 4.42

Table 176

Effect of diets containing cowpea and tur dhal , raw and autoclaved, at 10% protein level with supplements of methionine and tryptophane, on the weight of pancreas.

(Diets F, G, H and I)

(Average values with standard error)

Diets	wt. of rats (g.)	wt. of pancreas (g.)	wt. of pancreas/ 100g. rat (g.)	pancreas dry wt. (g.)	Moisture %
F	82.6± 1.26	0.4025± 0.0129	0.4941± 0.0215	0.1441± 0.0075	64.05± 1.46
G	97.1± 1.55	0.3417± 0.0177	0.3528± 0.0197	0.1449± 0.0104	63.50± 7.03
H	102.8± 3.61	0.3225± 0.0122	0.2833± 0.0490	0.1271± 0.0096	63.04± 4.11
I	119.6± 4.27	0.2500± 0.0218	0.2075± 0.0511	0.1361± 0.0089	43.11± 4.42

Table 177

Analysis of variance-Pancreatic weights

Source	df.	SS.	MSS.	F.
Between feeds	4	0.4983	0.1246	15.11**
Error	45	0.3710	0.0082	
Total	49	0.8693		

** significant at 1% level

Critical difference:

0.1024 at 5% level

0.1348 at 1% level

Mean values:

$\bar{F}$ = 0.4941 $\bar{G}$ = 0.3528 $\bar{H}$ = 0.2833

$\bar{I}$ = 0.2075 $\bar{C}$ = 0.4156

Average $\bar{c}$ 44.5± 59.8± 76.6± 88.6± 107.0±

Standard Error $\frac{0.28}{}$ $\frac{}{}$ $\frac{}{}$ $\frac{2.95}{}$ $\frac{4.43}{}$

THIRD SERIES OF EXPERIMENTS

Table 178

Body weight in g. of animals receiving diets containing autoclaved cowpea and tur dhal at 18% protein level on nitrogen basis

Diet J

Rat No.	Weeks				
	0	1	2	3	4
1	49.0	58.0	67.0	77.0	91.0
2	44.0	62.0	78.0	87.0	99.0
3	45.0	57.0	77.0	83.0	95.0
4	46.0	58.0	76.0	84.0	101.0
5	46.0	58.0	73.0	84.0	107.0
6	42.0	61.0	85.0	101.0	120.0
7	43.0	61.0	79.0	97.0	119.0
8	41.0	63.0	78.0	96.0	120.0
Average $\bar{c}$ Standard Error	44.5 ± 0.28	59.8 ± 0.25	76.6 ± 1.28	88.6 ± 2.95	107.0 ± 4.43

Table 179

Diet K

Rat No.	Weeks				
	0	1	2	3	4
1	44.0	54.0	65.0	74.0	81.0
2	51.0	57.0	74.0	84.0	96.0
3	40.0	53.0	68.0	78.0	88.0
4	43.0	57.0	71.0	82.0	94.0
5	43.0	61.0	80.0	88.0	99.0
6	51.0	58.0	64.0	74.0	86.0
7	49.0	56.0	66.0	72.0	80.0
8	47.0	52.0	61.0	71.0	82.0
Average $\bar{c}$ Standard Error	$46.0 \pm \frac{}{1.44}$	$56.0 \pm \frac{}{1.03}$	$68.6 \pm \frac{}{2.17}$	$77.9 \pm \frac{}{2.19}$	$88.3 \pm \frac{}{2.58}$

Table 180

Red blood cell concentration of animals maintained on diets J, K and L

Diet L

Rat No.	Weeks				
	0	1	2	3	4
1	45.0	69.0	87.0	103.0	121.0
2	40.0	60.0	76.0	90.0	103.0
3	40.0	61.0	80.0	92.0	107.0
4	41.0	63.0	81.0	93.0	110.0
5	43.0	63.0	81.0	104.0	129.0
6	45.0	66.0	82.0	102.0	118.0
7	42.0	64.0	83.0	99.0	125.0
8	44.0	59.0	77.0	102.0	118.0
Average $\bar{c}$ Standard Error	42.5 $\pm$ 0.23	63.1 $\pm$ 1.15	80.9 $\pm$ 1.22	98.1 $\pm$ 1.97	116.4 $\pm$ 1.01

Table 181

Red blood cell concentration of animals maintained on diets J, K and L
Diet J

Rat No.	Weeks				
	0	1	2	3	4
1	6.50	6.07	6.35	6.41	6.51
2	7.02	7.04	7.25	7.83	8.24
3	7.42	7.72	7.56	7.74	8.54
4	7.80	8.02	7.88	7.14	7.22
5	7.89	7.98	7.84	7.99	8.86
6	7.69	5.64	7.49	7.86	7.95
7	6.54	6.47	7.05	7.41	8.17
8	7.03	7.39	7.43	8.01	7.17
Average $\bar{c}$	7.23±	7.04±	7.35±	7.54±	7.83±
Standard Error	0.19	0.16	6.17	6.19	0.28

Table 182

Diet K

Rat No.	Weeks				
	0	1	2	3	4
1	7.10	7.04	7.11	7.20	7.25
2	7.45	7.58	7.56	7.78	7.24
3	7.43	7.80	7.84	7.95	8.60
4	6.45	6.50	6.60	6.91	8.26
5	6.04	6.14	6.25	6.58	8.51
6	6.00	5.89	6.43	7.03	8.60
7	6.78	7.51	7.53	7.84	8.36
8	6.13	6.13	6.14	6.54	7.39
Average $\bar{c}$	6.67±	6.82±	6.93±	7.22±	8.02±
Standard Error	0.21	0.26	0.23	0.19	0.22

Table 183

Diet L

Rat No.	Weeks				
	0	1	2	3	4
1	7.10	7.02	7.50	7.63	7.61
2	7.43	7.70	7.47	7.59	8.48
3	7.35	7.27	7.30	7.45	8.31
4	6.91	6.27	7.04	7.54	7.67
5	6.54	6.99	7.84	7.99	7.84
6	7.01	6.56	7.01	7.45	8.32
7	6.59	6.99	7.10	7.43	8.41
8	6.54	6.62	7.35	7.85	8.03
Average $\bar{c}$	6.93±	6.92±	7.32±	7.61±	8.08±
Standard Error	0.12	0.16	0.01	0.01	0.12

Table 184

Haemoglobin concentration of animals maintained on diets J, K and L

Diet J

Rat No.	Weeks				
	0	1	2	3	4
1	13.7	14.3	14.4	14.5	14.7
2	13.0	13.8	13.7	15.0	15.0
3	12.8	13.7	13.5	13.6	13.9
4	13.0	13.4	13.8	14.0	14.5
5	12.7	13.5	13.3	14.0	14.1
6	13.4	13.8	13.2	14.1	14.4
7	13.4	12.6	13.0	15.0	15.0
8	14.0	15.3	15.4	15.3	14.5
Average $\bar{c}$ Standard Error	13.25± 0.16	13.80± 0.27	13.78± 0.27	14.43± 0.21	14.51± 0.14

Table 185

Diet K

Rat No.	Weeks				
	0	1	2	3	4
1	13.5	13.8	13.7	14.1	14.2
2	13.8	14.1	14.8	14.9	15.1
3	13.2	13.6	14.0	15.1	16.0
4	13.2	14.3	14.5	15.2	15.0
5	13.2	14.0	14.1	15.0	15.3
6	14.8	15.3	15.3	14.2	16.5
7	13.8	14.6	14.6	15.6	14.9
8	13.3	12.7	14.2	15.0	14.0
Average $\bar{c}$ Standard Error	13.60± 0.19	13.97± 0.25	14.40± 0.18	14.88± 0.18	15.12± 0.29

Table 186

Diet L

Rat No.	Weeks 0	1	2	3	4
1	13.7	14.6	15.2	15.2	15.1
2	14.8	15.0	15.2	12.4	15.6
3	14.7	15.0	15.3	15.1	15.6
4	13.8	13.6	15.0	15.4	14.7
5	14.0	16.1	15.8	15.0	15.0
6	14.1	14.1	14.5	15.2	15.4
7	14.3	15.0	15.0	15.4	15.0
8	14.3	14.0	14.2	15.8	15.4
Average $\bar{c}$ Standard Error	14.21± 0.14	14.67± 0.28	15.02± 0.17	14.93± 0.12	15.22± 0.11

Table 187

Summarised data* on body weight, red blood cell, haemoglobin and plasma protein concentrations of animals maintained on diets J, K and L.
(Vide Tables 178-186)

Diets	No. of animals		Days on experiment				
			0	7	14	21	28
J	8	weight (g.)	44.5±0.28	59.8±0.25	76.6±0.95	88.6±2.95	107.0±4.43
		R.B.C.(mill./mm^3)	7.23±0.19	7.04±0.16	7.35±0.17	7.54±0.19	7.83±0.28
		Haemoglobin (g./100 ml.)	13.6±0.19	13.9±0.25	14.4±0.18	14.9±0.18	15.1±0.29
K	8	weight (g.)	46.0±1.44	56.0±1.03	68.6±2.17	77.9±2.19	88.3±2.58
		R.B.C.(mill./mm^3)	6.67±0.21	6.82±0.26	6.93±0.23	7.22±0.19	8.02±0.22
		Haemoglobin (g./100 ml.)	13.3±0.16	13.8±0.27	13.8±0.27	14.4±0.21	14.5±0.14
L	8	weight (g.)	42.5±0.23	63.1±1.15	80.9±1.22	98.1±1.97	116.4±1.01
		R.B.C.(mill./mm^3)	6.93±0.12	6.92±0.16	7.32±0.01	7.61±0.01	8.08±0.12
		Haemoglobin (g./100 ml.)	14.2±0.14	14.7±0.28	15.0±0.17	14.9±0.12	15.2±0.11

* Mean values (8 animals/group) with standard error.

Table 188

Analysis of variance-weight gain

Source	df.	SS.	MSS.	F.
Between feeds	2	4105.58	2052.79	17.13**
Error	21	2516.38	119.83	
Total	23	6621.96		

** Significant at 1% level

Critical values:

11.38 at 5% level
15.39 at 1% level

Mean values:

J = 107.0, K = 88.3, L = 116.4.

Table 189

Analysis of variance--Red blood cells

Source	df.	SS.	MSS.	F.
Between feeds	2	0.28	0.14	0.37
Error	21	7.92	0.377	
Total	23	8.20		

Not significant

Table 190

Analysis of variance--Haemoglobin

Source	df.	SS.	MSS.	F
Between feeds	2	2.38	1.19	0.02
Error	21	234.06	11.15	
Total	23	236.44		

Not significant

Table 191

Weight gain, feed consumption, protein efficiency values of animals fed diets J, K and L at 18% protein level

Diet J

Rat No.	Initial wt.(g.)	Final wt.(g.)	Wt.gain (g.)	Food intake (g.)	Protein intake (g.)	Protein efficiency value
1	49.0	91.0	42.0	187.2	33.7	1.25
2	44.0	99.0	55.0	217.8	39.2	1.40
3	45.0	95.0	50.0	172.8	31.1	1.61
4	46.0	101.0	55.0	164.7	29.6	1.86
5	46.0	107.0	61.0	164.7	29.6	2.06
6	42.0	124.0	82.0	215.1	38.7	2.12
7	43.0	119.0	76.0	225.0	40.5	1.88
8	41.0	120.0	79.0	217.8	39.20	2.02
Average $\bar{c}$ Standard Error	44.5± 0.28	107.0± 4.43	62.5± 1.65	195.6± 9.21	35.2± 1.66	1.87± 0.11

Table 192

Diet K

Rat No.	Initial wt.(g.)	Final wt.(g.)	Wt. gain (g.)	Food intake (g.)	Protein intake 9g.)	Protein efficiency value
1	44.0	81.0	37.0	130.5	23.5	1.57
2	51.0	96.0	45.0	144.0	25.9	1.74
3	40.0	88.0	48.0	144.0	25.9	1.85
4	43.0	94.0	51.0	179.1	32.2	1.58
5	43.0	99.0	56.0	162.0	29.2	1.92
6	51.0	86.0	35.0	143.1	25.8	1.36
7	49.0	80.0	31.0	136.8	24.0	1.29
8	47.0	82.0	35.0	118.8	21.4	1.64
Average ± Standard Error	46.0 ± 0.44	88.3 ± 2.58	42.3 ± 3.17	144.8 ± 6.57	25.9 ± 1.34	1.6 ± 0.07

Table 193

Diet L

Rat No.	Initial Weight (g.)	Final Weight (g.)	Weight gain (g.)	Food intake (g.)	Protein intake (g.)	Protein efficiency value
1	45.0	121.0	76.0	207.0	37.3	2.04
2	40.0	103.0	63.0	189.9	34.2	1.84
3	40.0	107.0	67.0	206.1	37.6	1.78
4	41.0	110.0	69.0	186.3	33.5	2.06
5	43.0	129.0	86.0	220.5	39.7	2.17
6	45.0	118.0	73.0	218.7	39.4	1.85
7	42.0	125.0	83.0	216.0	38.9	2.13
8	44.0	118.0	74.0	193.5	34.8	2.13
Average $\bar{c}$ Standard Error	42.5± 0.23	116.4± 1.01	73.9± 2.75	204.7± 4.75	36.9± 0.27	2.00± 0.05

Table 194

Summarised data* on weight gain, food intake, protein intake, protein efficiency values, fed efficiency values and of animals maintained on diets J, K & L.

Diets	Initial body wt. (g)	final body wt. (g)	weight gain (g)	food intake (g)	protein intake (g)	protein efficiency values	fed efficiency values
J	44.5±	107.0±	62.5±	195.6±	35.2±	1.77±	
	0.28	4.43	1.65	9.21	1.66	0.11	
K	46.0±	88.3±	42.3±	114.8±	25.9±	1.61±	
	0.44	2.58	3.17	6.57	1.34	0.07	
L	42.5±	116.4±	73.9±	204.8±	36.9±	2.00±	
	0.23	1.01	2.75	4.75	0.27	0.05	

* Average of 8 animals per group with standard error.

Table 195

Analysis of variance-Protein efficiency value.

Source	df.	SS.	MSS.	F.
Between feeds	2	0.5877	0.2938	4.6**
Error	21	1.3360	0.0636	
Total	23	1.9237		

**Significant at 1% level.

Critical difference

0.26 at 5% level

0.36 at 1% level

Mean values

J = 1.77 K = 1.61 L = 2.00

Table 196

Effect of feeding Diets M, N, O, P and Q containing raw and autoclaved cowpea and tur dhal on reproduction and lactation

Diet M

Rat No.	Body wt. of rats (g.)	No. of young ones born	Av. birth weight of young ones	Total litter wt. at birth (g.)	No. of young ones survived	Average weaning wt. (g.)
1	181.0	5	5.1	25.5	3	16.5
2	155.0	6	4.9	29.3	5	18.0
3	175.0	8	4.4	35.0	6	14.8
4	102.0	4	5.3	21.1	4	18.5
5	180.0	5	4.5	22.4	5	17.5
6	159.0	5	4.5	22.4	5	19.0
Average ± Standard Error	173.7	5.5	4.8	25.9	4.7	17.4

Table 197

Diet N

Rat No.	Body wt. of rats (g.)	No. of young ones born	Av. birth weight of young ones (g.)	Total litter wt. at birth (g.)	No. of young ones survived	Average weaning wt. (g.)
1	158.0	5	4.4	22.2	4	15.5
2	165.0	4	5.3	21.1	3	14.5
3	130.0	5	3.4	17.2	4	15.0
4	177.0	4	3.8	15.2	4	15.0
5	174.0	5	3.9	19.4	3	16.5
6	156.0	4	4.4	17.6	4	17.5
Average	160.0	4.5	4.2	18.8	3.6	15.7

Table 198

Diet O

Rat No.	Body st. of rats (g.)	No. of young ones born	Av. birth weight of young ones (g.)	Total litter wt. at birth (g.)	No. of young ones survived	Average weaning wt. (g.)
1	159.0	5	5.2	25.8	5	25.0
2	185.0	6	5.2	31.2	6	22.5
3	192.0	6	5.0	30.2	6	25.0
4	158.0	5	5.1	25.4	5	26.5
5	178.0	6	4.7	28.2	6	28.5
6	187.0	4	4.8	19.2	4	25.5
7	190.0	7	5.0	35.4	7	20.5
8	155.0	5	4.6	23.3	5	25.0
Average	175.5	5.5	4.0	27.5	5.5	24.8

Table 199

Diet P

Rat No.	Body wt. of rats (g.)	No. of young ones born	Av. birth weight of young ones (g.)	Total litter wt. at birth (g.)	No. of young ones survived	Average weaning wt. (g.)
1	141.0	8	4.4	35.5	6	20.8
2	155.0	9	3.6	32.2	8	19.5
3	194.0	2	4.4	8.8	2	21.5
4	168.0	2	5.3	10.7	2	22.0
5	192.0	8	4.8	38.7	8	15.5
6	189.0	8	4.3	34.6	8	15.0
7	169.0	3	4.2	12.6	3	19.0
Average	172.6	5.7	4.4	24.7	5.3	19.0

Table 200

Diet Q

Rat No.	Body wt. of rats (g.)	No. of young ones born	Av. birth weight of young ones	Total litter wt. at birth (g.)	No. of young ones survived	Average weaning wt. (g.)
1	160.0	2	4.5	9.0	2	19.5
2	153.0	5	4.5	22.6	3	20.5
3	163.0	6	4.5	27.0	4	15.8
4	130.0	5	3.4	17.2	5	18.5
5	177.0	4	3.7	14.9	4	20.5
6	158.0	5	4.0	20.1	5	16.5
7	169.0	5	4.5	22.7	5	18.0
Average	158.6	4.6	4.2	19.1	4	18.5

Table 201

Effect of diets M, N, O, P and Q on reproduction and lactation

	Diet M	Diet N	Diet O	Diet P	Diet Q
1. No. of female rats mated	10	10	10	10	10
2. No. of fertile females	6	6	8	7	7
3. No. of young born	33	27	44	40	32
4. No. of young survived	28	22	44	37	28
5. Litter size	5.5	4.5	5.5	5.7	4.6
6. Average birth wt. in g.	4.8	4.2	4.9	4.4	4.1
7. Average weaning wt. in g.	17.4	15.7	24.8	19.0	18.5

DISCUSSION

The results obtained during the course of the present study are discussed under separate heads.

FIRST SERIES OF EXPERIMENTS

Feeding trials with raw and autoclaved cowpea and tur dhal diets each containing 10% protein on nitrogen basis

Growth

From the summarised data on body weight presented in Table 25, represented in Figures 3 and 5 and from the statistical analyses of the results set out in Table 29, it will be seen that the diets containing raw cowpea (Diet A) and raw tur dhal (Diet B) do not support growth of rats, the average weight gain of animals during the experimental period of 4 weeks being 2.0 g. and 0.8 g. respectively, as against 43.9 g. obtained with the control diet C. As regards diets containing autoclaved cowpea (Diet D) and autoclaved tur dhal (Diet E), both diets promote growth of rats, the average gain in weight during the experimental period of 4 weeks being 25.2 g. and 26.8 g. respectively.

The results clearly indicate that although autoclaving of cowpea and tur dhal promotes their growth promoting abilities, the diets containing these two pulses (Diets D

FIG. 3

GROWTH RATES ON DIETS A, B, C, D & E.

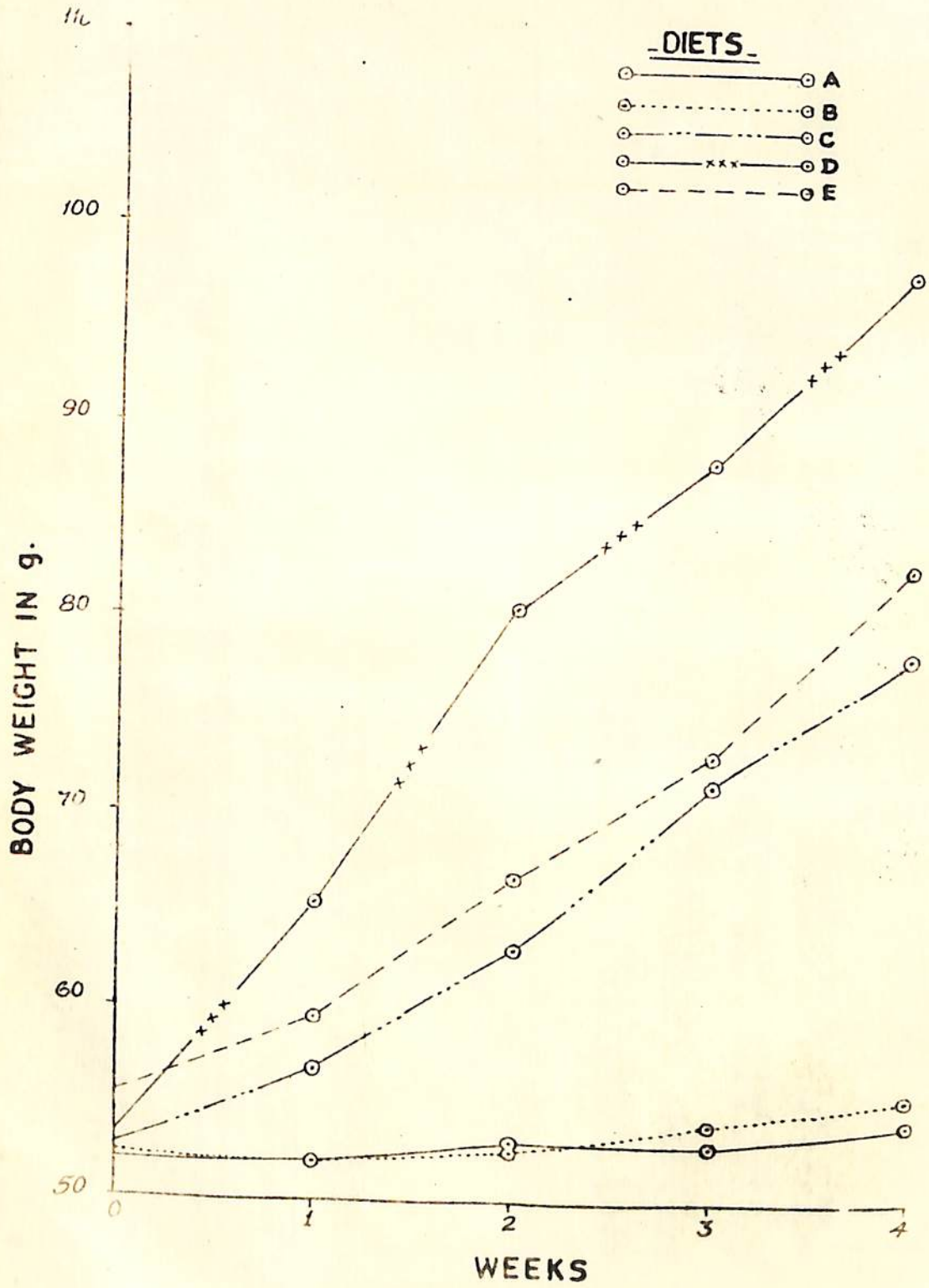
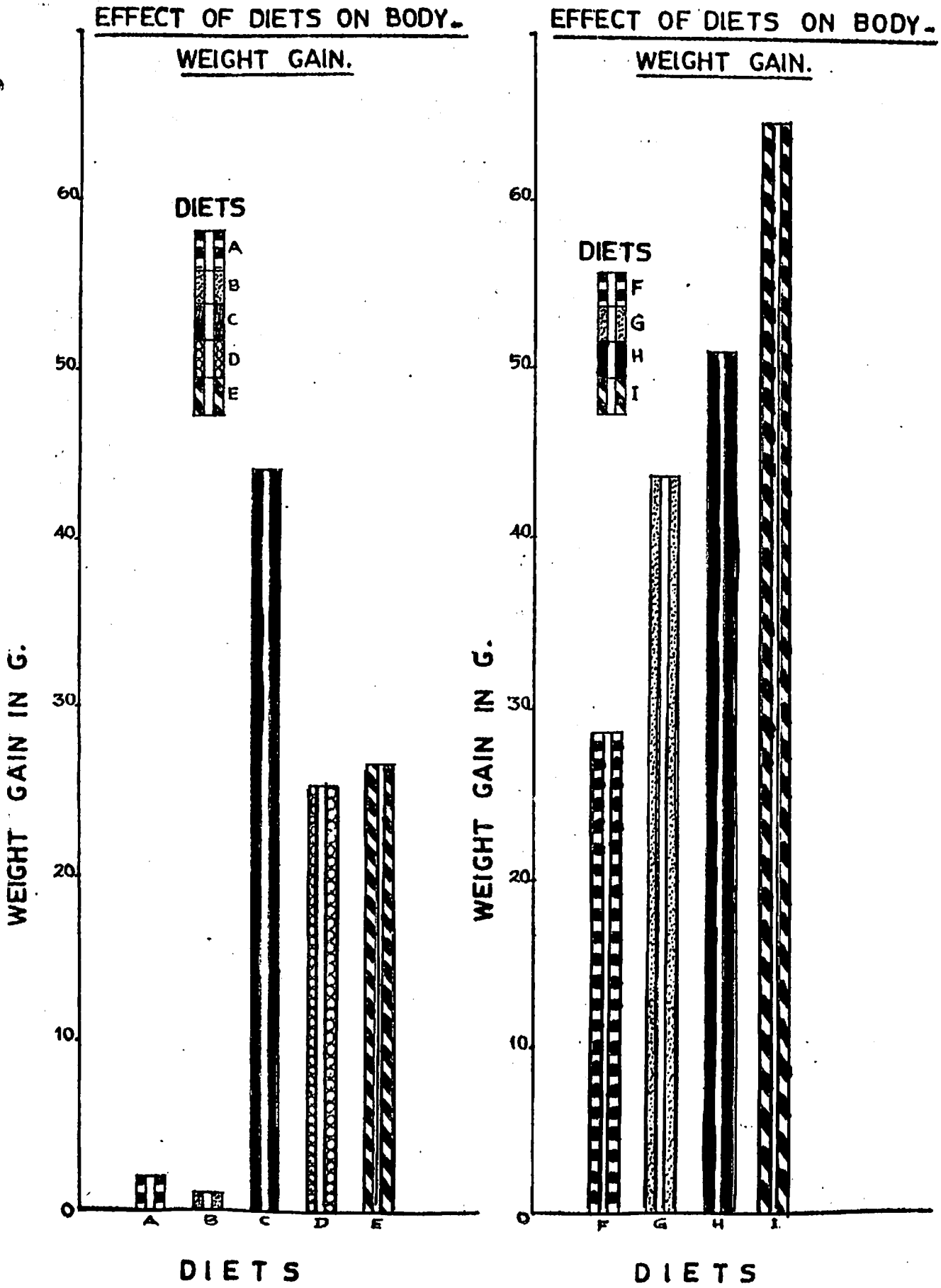


FIG. 5


EFFECT OF DIETS ON BODY-
WEIGHT GAIN.
DIETS
A
B
C
D
E
60
50
40
30
20
10
0
WEIGHT GAIN IN G.
A
B
C
D
E
DIETS
EFFECT OF DIETS ON BODY-
WEIGHT GAIN.
DIETS
F
G
H
I
60
50
40
30
20
10
0
WEIGHT GAIN IN G.
F
G
H
I
DIETS

and E) are far inferior in this respect to the control diet containing 10% casein (Diet C).

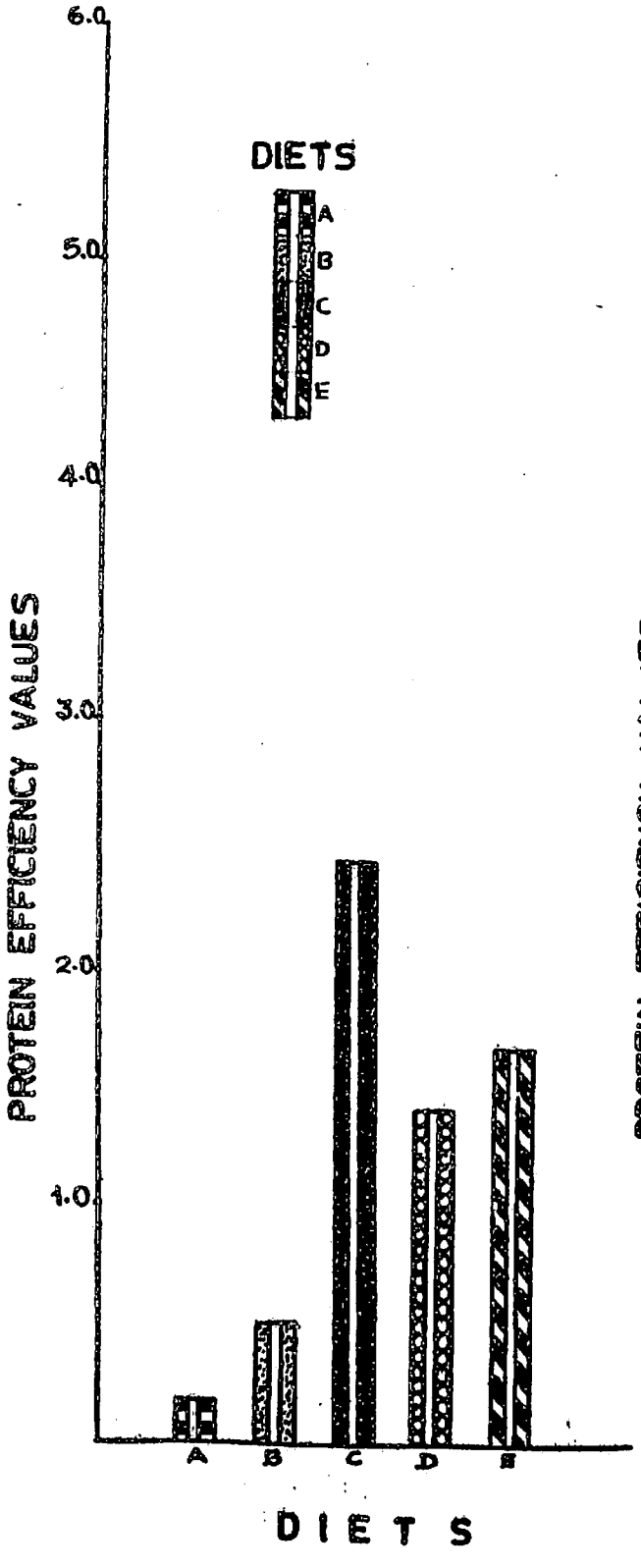
Data on food consumption of animals fed the different diets do not show any marked variation, although animals receiving the raw cowpea diet (Diet A) and the raw tur dhal diet (Diet B) consume comparatively less feed.

Protein efficiency values

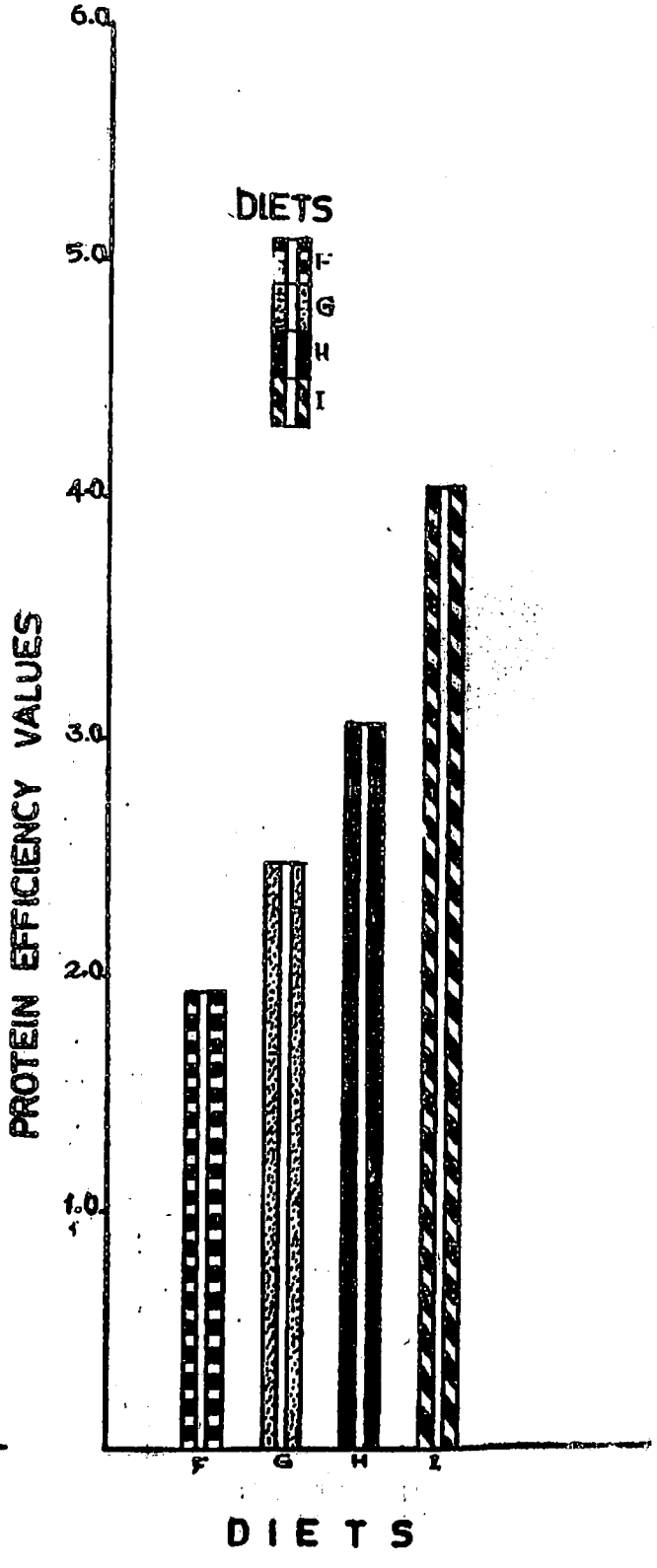
The summarised data presented in Table 26, represented in Figure 6 and the statistical analyses of the results set out in Table 30 clearly indicate that both diets A and B, containing raw cowpea and raw tur dhal respectively, register significantly lower protein efficiency values as compared with the control diet containing casein (Diet C). There is no significant difference between the two raw pulse diets in this respect. As between the autoclaved turdhals (Diets D and E respectively), there is no significant difference between them, both diets giving significantly higher protein efficiency values than the corresponding raw pulse diets (Diet A and Diet B), but significantly lower values as compared with the control diet (Diet C).

FIG. 6

PROTEIN EFFICIENCY VALUES.



PROTEIN EFFICIENCY VALUES.



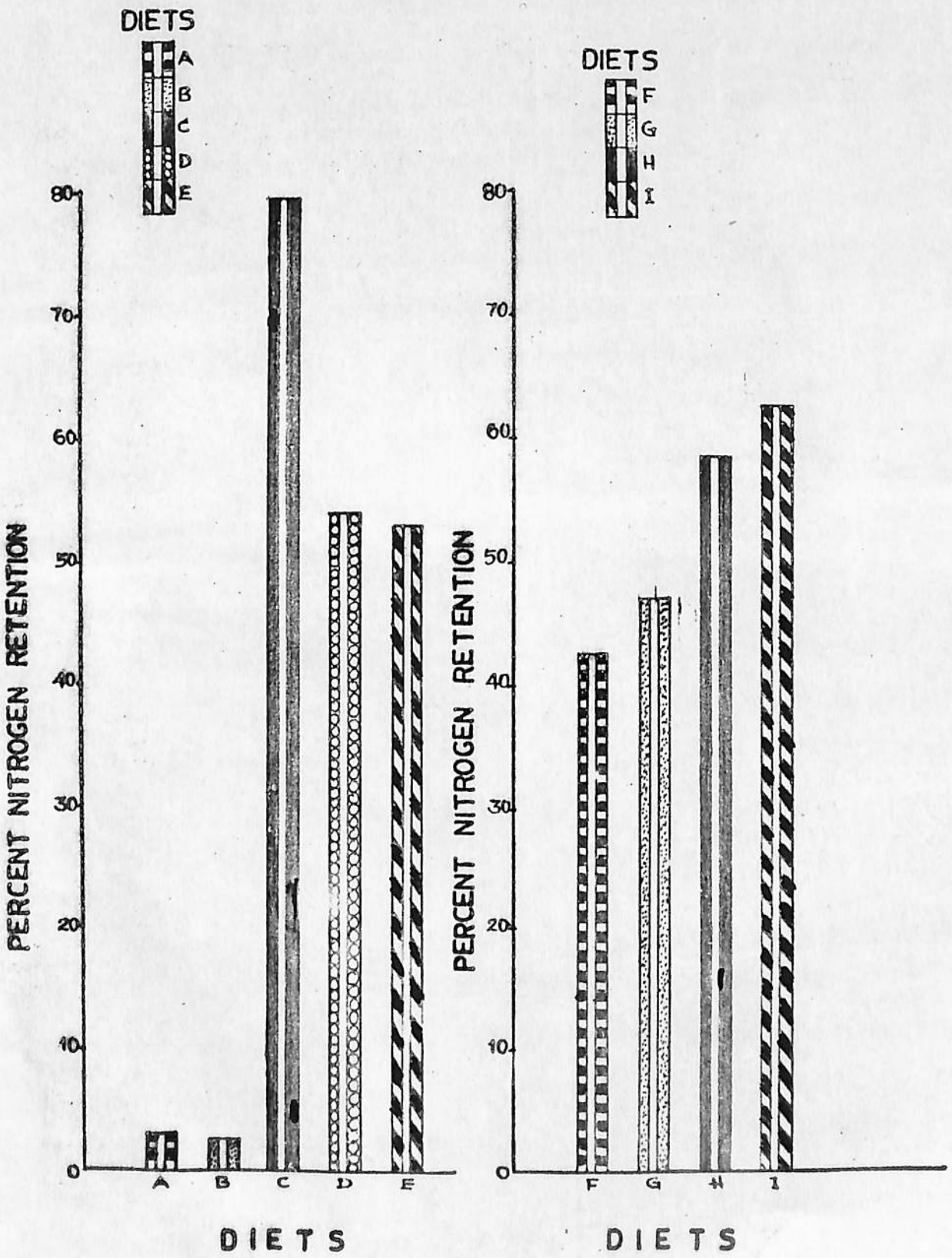
Nitrogen balance

From the summarised data on nitrogen retention presented in Table 27, represented in Figure 7 and from the statistical analyses of the results given in Table 31, it can be seen that rats maintained on the Control diet C retain significantly higher nitrogen than those fed the raw as well as the autoclaved cowpea and the tur dhal diets (Diets A and B respectively and Diets D and E, respectively, animals receiving the autoclaved pulse diets (Diets D and E) showing significantly higher values than those fed the raw pulse diets (Diets A and B). As between the autoclaved cowpea diet D and autoclaved tur dhal diet D, there is no significant difference.

Digestibility Coefficients

Summarised data on the digestibility coefficients of protein, carbohydrate and fat presented in Table 28, and the statistical analyses of the results given in Tables 32, 33 and 34 respectively, clearly indicate that values for the digestibility coefficients of these nutrients in autoclaved cowpea and autoclaved tur dhal diets (Diets D and E respectively) are significantly higher than for those in the respective raw diets (Diets

FIG. 7


NITROGEN RETENTION ON DIETS A, B, C, D & E.
NITROGEN RETENTION ON DIETS F, G, H & I.
DIETS
A
B
C
D
E
F
G
H
I
80
70
60
50
40
30
20
10
0
PERCENT NITROGEN RETENTION
A
B
C
D
E
F
G
H
I
DIETS
DIETS

A and B. Diets A and B show no significant difference between themselves in this regard. Digestibility coefficients of nutrients in the control diet C are significantly higher than those of nutrients in the other diets (Diets A, B, D and E). According to Jaffe (1950) the low protein digestibility of legume grains has been observed not only among species but also among varities of the same species. For example, Cajanus cajan showed a protein digestibility of 59% in contrast to other varieties in respect of which values as high as 90% were obtained.

Blood Values

The summarised data on red blood cell and haemoglobin and plasma protein concentrations presented in Tables 46 and 47 respectively and the statistical analyses of the respective results given in Tables 48, 49 and 50 reveal no significant differences between the diets A, B and C in their ability to support these formed elements of blood.

Concentration of glutamic-oxalo acetic transaminase and glutamic-pyruvic transaminase in serum and liver

The summarised data on the glutamic-oxalo acetic transaminase and glutamic-pyruvic transaminase in serum

and liver presented in Table 56 and the statistical analyses of the results given in Tables 57 to 60 indicate that the experimental diets used in the present study do not show any significant differences between them in these respects although the raw cowpea diet (Diet A) and the raw tur dhal diet (Diet B) give comparatively lower values for glutamic pyruvic transaminase.

Concentration of glycogen in liver

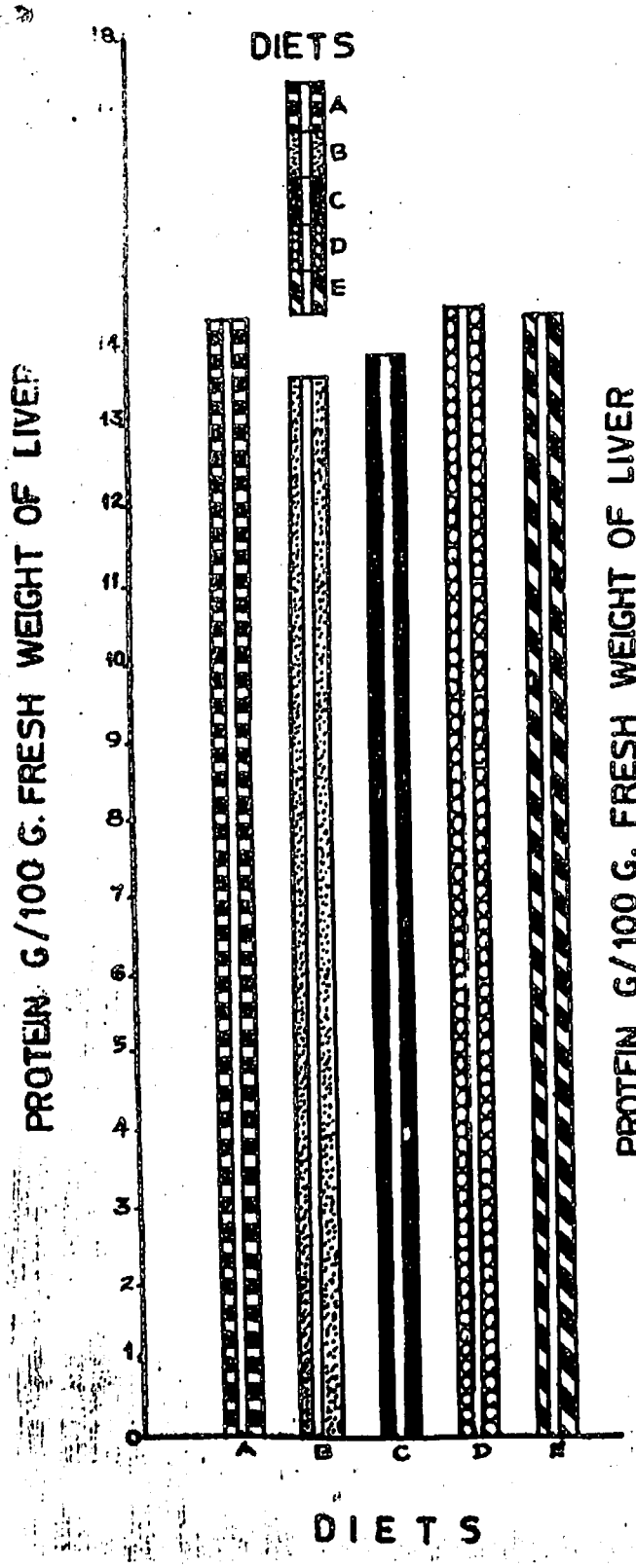
Data on liver glycogen consolidated in Table 62 and statistical analyses of the results given in Table 63 do not disclose any significant differences between the experimental diets, although slightly higher values are obtained on the control diet (Diet C) and on diet containing autoclaved cowpea and tur dhal (Diets D and E respectively).

Liver fat and liver protein contents

From the summarised data on liver fat and liver protein contents presented in Table 69, represented in figures 8 and 9 respectively and from the statistical analyses of the results given in Tables 70 and 71 respectively, it can be seen that animals maintained on diets containing raw cowpea and raw tur dhal (Diets A and B respectively) show significantly higher liver fat

FIG. 8

EFFECT OF DIETS A,B,C,D & E ON LIVER PROTEIN CONTENT.



EFFECT OF DIETS F,G,H & I ON LIVER PROTEIN CONTENT.

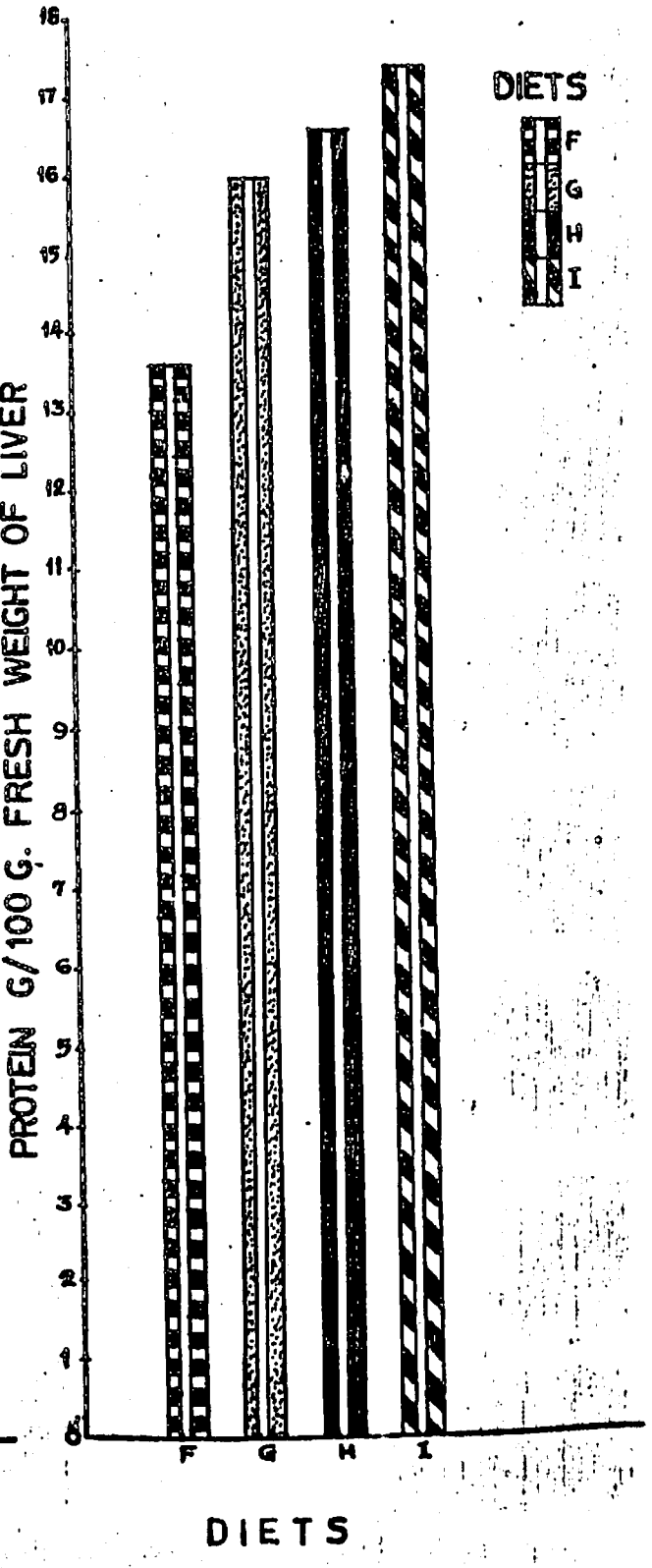
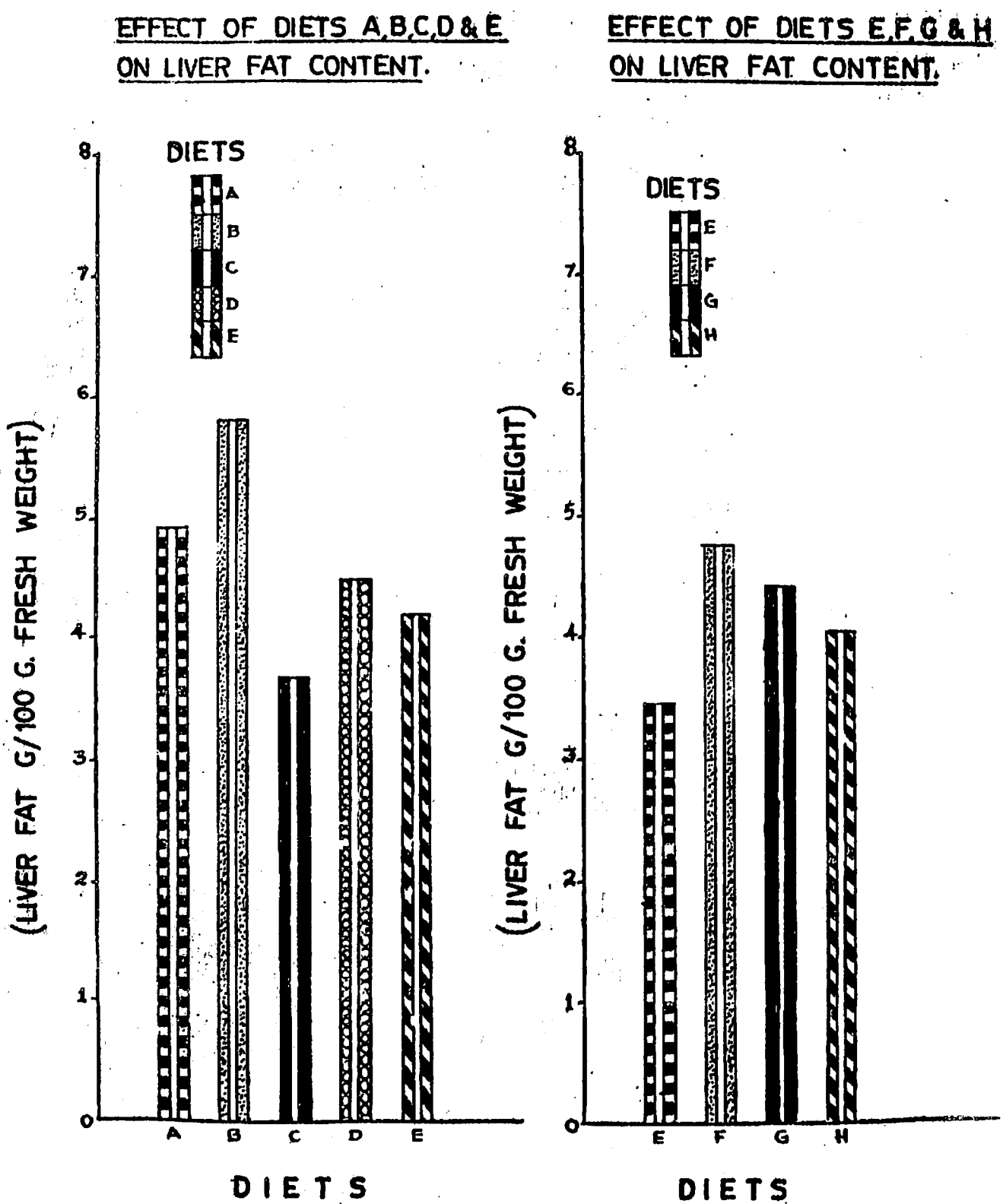


FIG. 9


EFFECT OF DIETS A,B,C,D & E ON LIVER FAT CONTENT.
DIETS
A
B
C
D
E
(LIVER FAT G/100 G. FRESH WEIGHT)
0
1
2
3
4
5
6
7
8
A
B
C
D
E
DIETS
EFFECT OF DIETS E,F,G & H ON LIVER FAT CONTENT.
DIETS
E
F
G
H
(LIVER FAT G/100 G. FRESH WEIGHT)
0
1
2
3
4
5
6
7
8
E
F
G
H
DIETS

content as compared with those receiving the control diet C and the autoclaved tur dhal and cowpea diets (Diets D and E respectively). As between the autoclaved pulse diets (Diets D and E), no significant difference is observed.

As regards the liver protein content, no significant difference is discernible between the diets (Diets A, B, C, D and E) used in the present study.

INTERNAL ORGAN WEIGHTS

Liver, Kidney and Heart

From the summarised data on internal organ weights presented in Table 77 and from the statistical analyses of the results furnished in Tables 78 to 81, it would appear that the autoclaved pulse diets tend to increase significantly the weights of liver, kidney and heart as compared with the control diet C and the raw pulse diets A and B.

Caecae

From the summarised data on caecal weights with and without contents, presented in Table 87 and from the statistical analyses of the results set out in Tables 88

and 89 respectively, it will be evident that animals maintained on diets containing raw cowpea and raw tur dhal (Diets A and B) show significantly higher caecal weights as compared with those receiving the control diet C. As between the animals fed diets A and B, a significantly higher caecal weight is observed in the case of the latter. As regards the autoclaved pulse diets (Diets D and E), significantly higher caecal weights are observed in the case of animals receiving the raw tur dhal diet (Diet B) as compared with those maintained on the autoclaved tur dhal diet (Diet E).

Pancreas

From the summarised data on pancreatic weights of animals, presented in Table 95 and from the statistical analyses of the results given in Table 96, it can be seen that animals maintained on the control diet (Diet C) and on the autoclaved pulse diets (Diets D and E) show significantly lower weights for pancreas as compared with those fed the raw pulse diets (Diets A and B). While no significant difference is seen in pancreatic weights between animals receiving raw cowpea diet (Diet A) and autoclaved cowpea diet (Diet D), a significantly higher pancreatic weight is observed in the case of

animals maintained on the raw tur dhal diet (Diet B) as compared with those fed diet containing autoclaved tur dhal (Diet E).

SECOND SERIES OF EXPERIMENTS

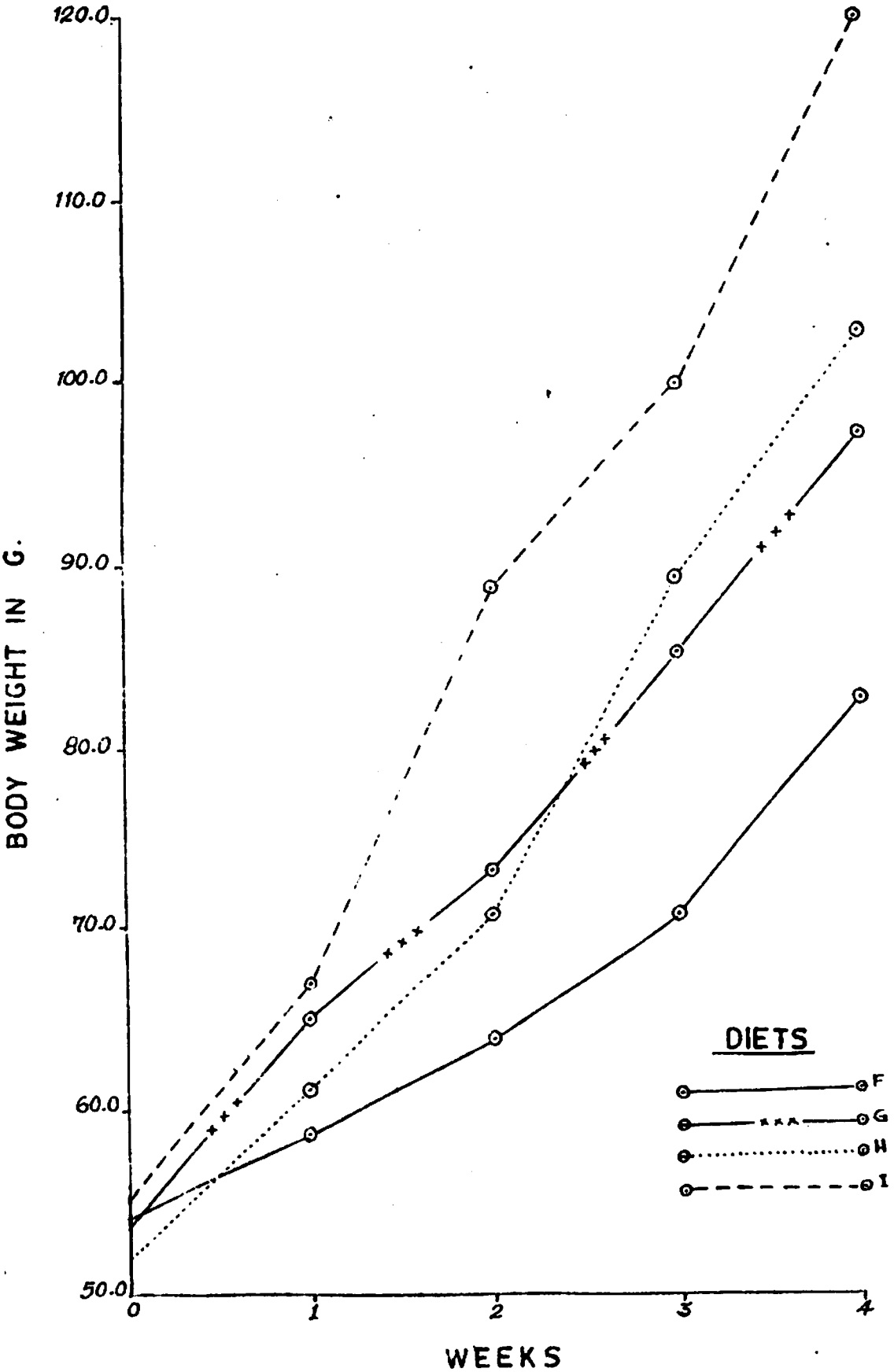
Feeding trials with raw and autoclaved cowpea and tur dhal diets each containing 10% protein on nitrogen basis, supplemented with L-methionine and L-tryptophane

Growth

The summarised data presented in Table 113 represented in Figure 4 and statistical analyses of the results set out in Table 117 indicate that the diets containing raw cowpea and raw tur dhal both supplemented with methionine and tryptophane (Diets F and G respectively) promote growth in rats, the average weight gain on the respective diets during the experimental period of 4 weeks being 28.5 g. and 43.6 g. as against 2.0 g. and 0.8 g. respectively obtained on the raw cowpea and raw tur dhal diets in the first series of experiments (Table No.25). As between the two amino acid supplemented raw cowpea and raw tur dhal diets (Diets F and G respectively), a significantly higher growth rate is obtained with the latter. As regards the amino acid supplemented autoclaved

FIG. 4

GROWTH RATES ON DIETS F, G, H & I.



pulse diets (Diets H and I), it is seen that both diets promote significantly higher growth than the corresponding raw pulse diets, diet I containing autoclaved tur dhal exerting significantly higher influence in this respect than diet H containing autoclaved cowpea. It is seen further that the autoclaved pulse diets supplemented with methionine and tryptophane (Diets H and I) promote significantly higher growth in rats than the control diet C.

From a critical comparison of the data with the same obtained in the first series of experiments, it will be seen that on the autoclaved cowpea diet (Diet D), essentially identical growth rate is obtained as on the raw cowpea diet supplemented with methionine and tryptophane (Diet F) but on the other supplementation of autoclaved tur dhal with methionine and tryptophane (Diet I) brings about on feeding significantly higher rate of growth than both the raw and autoclaved tur dhal (Diets B and E).

Protein efficiency values

From the summarised data on protein efficiency values presented in Table 114, represented in Figure 6 , statistical analyses of the results detailed in Table 118

and from a critical comparison of the results with those obtained in the First series of experiments (Table No.26) it can be seen that supplementation of the diets containing raw or autoclaved cowpea (Diets F and H) and raw or autoclaved tur dhal (Diets G and I) with methionine and tryptophane significantly enhances their protein efficiency values. As between the raw pulse diets supplemented with methionine and tryptophane (Diets F and G), significantly higher protein efficiency value is obtained for diet G, the value being almost identical with that for the control diet C. As between the autoclaved cowpea and tur dhal diets supplemented with methionine and tryptophane (Diets H and I), it is seen that significantly higher protein efficiency values are obtained for sm both these diets as compared with the control, the supplemented tur dhal diet (Diet I) registering a significantly higher value than the amino acid supplemented autoclaved cowpea diet (Diet H).

Nitrogen balance

From the summarised data on nitrogen retention presented in Table 115, represented in Figure 7, statistical analyses of the results set out in Table 119 and from a critical comparison of the same with those obtained

in the First series of experiments (Table 27), it can be seen that autoclaving cowpea and tur dhal (Diets H and I) brings about on methionine and tryptophane supplementation significantly higher nitrogen retention in rats than the raw pulse diets supplemented with methionine and tryptophane (Diets F and G), maximum nitrogen retention being obtained in the case of the control diet. As between the amino acid supplemented raw and autoclaved cowpea flour diets (Diets F and H) on one hand and the amino acid supplemented raw and autoclaved tur dhal diets (Diets G and H) on the other, there is no significant difference.

Digestibility coefficients

The summarised data on digestibility coefficients of protein, fat and carbohydrate presented in Table 116, statistical analyses of the results set out in Tables 120, 121 and 122 respectively and a critical comparison of the data with those obtained in the First series of experiments (Table 28) show that supplementation with methionine and tryptophane significantly enhances protein digestibility whether the diets contain raw or autoclaved cowpea (Diets F and H) or raw or autoclaved tur dhal (Diets G and I). Between the raw cowpea and tur dhal diets supplemented with methionine and tryptophane

(Diets F and G) as also between the amino acid supplemented autoclaved cowpea and tur dhal diets (Diets H and I) no significant difference is observed in the digestibility of protein. Protein is found to be most digestible in the control diet. In regard to fat, supplementation with methionine and tryptophane (Diets F, G, H and I) does not appear to increase its digestibility. On the other hand, digestibility of carbohydrate in the amino acid supplemented raw cowpea diet (Diet F) is significantly increased as compared with the amino acid supplemented tur dhal diet (Diet G). In the case of the autoclaved pulse diets (Diets H and I), supplementation with methionine and tryptophane does not bring about any beneficial effect on the digestibility of carbohydrate in either case.

Blood values

The summarised data on red blood cell, presented in Table 132, and haemoglobin and plasma protein concentrations given in Table 133, statistical analyses of the results set out in Tables 134, 135 and 136 respectively and a critical comparison of the results with those obtained in the first series of experiments (Tables 46 and 47) reveal no significant difference in red blood cell and haemoglobin concentrations between animals maintained on cowpea and tur dhal both raw

and autoclaved with and without supplementation of methionine and tryptophane (Diets F, G, H and I). As regards plasma protein, significantly higher concentration is observed in animals receiving raw cowpea diet supplemented with methionine and tryptophane (Diet F) as compared with those maintained on the amino acid supplemented raw tur dhal diet (Diet G).

Concentration of glutamic-oxalo acetic transaminase and Glutamic pyruvic transaminase in serum and liver

Summarised data on glutamic-oxalo acetic transaminase and glutamic-pyruvic transaminase in serum and liver presented in Table 142 and statistical analyses of the results given in Tables 144 to 147 clearly indicate that animals receiving the various diets (Diets F, G, H and I) show no significant difference in respect of these enzyme concentrations. However, rats receiving the amino acid supplemented autoclaved cowpea and autoclaved tur dhal diets (Diets H and I) show slight increase in glutamic-pyruvic transaminase in serum and liver over those of rats maintained on diets containing raw cowpea and raw tur dhal supplemented with amino acids (Diet F and G respectively).

Concentration of glycogen in liver

The summarised data on liver glycogen presented in Table 143 and the statistical analyses of the results detailed in Table 148 do not show any significant difference in the liver glycogen content between the animals fed the different diets (Diets F, G, H and I).

Liver fat and liver protein contents

The summarised data on liver fat and liver protein contents presented in Table 153, represented in Figures 8 and 9 respectively, statistical analyses of the results furnished in Tables 154 and 155 respectively and a critical comparison of the results with those obtained in the first series of experiments (Table 69) show that animals fed the raw tur dhal diet supplemented with methionine and tryptophane (Diet G) possess significantly higher liver fat content as compared with those maintained on the amino acid supplemented raw cowpea diet (Diet F). As between the autoclaved pulse diets supplemented with methionine and tryptophane, no significant difference is observed (Diets H and I).

As regards liver protein content no significant difference is observed between animals receiving the various diets used in the present series of experiments (Diets F, G, H and I).

INTERNAL ORGAN WEIGHTS

Liver, spleen, kidney and heart

From the summarised data on internal organ weights presented in Table 160 and from the results of statistical analyses detailed in Tables 161 to 169, a significantly higher increase in the weight of livers of rats maintained on diets containing raw cowpea supplemented with methionine and tryptophane (Diet F) is discernible as compared with those of animals fed the amino acid supplemented tur dhal diet (Diet G). As between the animals maintained on the two autoclaved pulse diets supplemented with methionine and tryptophane (Diets H and I), no significant difference is observed in the liver weight. Apparently, the diets (Diets F, G, H and I) do not appear to exert any significant influence on the weights of heart and kidney.

Caecae

The summarised data on caecal weights with and without contents, presented in Table 169 and statistical analyses of the same detailed in Tables 170 and 171 respectively show that caecae with contents of animals maintained on diet G containing raw tur dhal supplemented with methionine and tryptophane have significantly higher

weights as compared with those of animals fed the amino acid supplemented raw cowpea diet (Diet F). As between the two amino acid supplemented autoclaved cowpea and autoclaved tur dhal diets (Diets H and I respectively), no significant difference is observed in this regard.

Animals receiving the different test diets (Diets F, G, H amd I) show no significant difference between them in respect of weights of caecae without contents.

Pancreas

The summarised data on pancreatic weights presented in Table 176 and the statistical analyses of the results set out in Table 177 show significantly higher pancreatic weights in the case of rats maintained on diet F containing raw cowpea supplemented with methionine and tryptophane, as compared with the same of animals receiving the amino acid supplemented tur dhal diet (Diet G). As between the amino acid supplemented autoclaved cowpea and autoclaved tur dhal diets (Diets H and I), no significant difference is observed. Between the amino acid supplemented raw tur dhal and autoclaved tur dhal diets (Diets G and H respectively), significantly higher pancreatic weight is observed in animals fed diet G containing raw tur dhal.

It has been reported that hypertrophy of pancreas represents one of the physiological effects produced by feeding raw soyabean in rats (Booth et al., 1960 and Alumot and Nitsan, 1961). Although several reasons have been advanced and conjectures made in regard to this phenomenon (Lyman and Lepkovsky, 1957; Melnick et al., 1946 and Lyman, 1957) based on the presence and concentration of protease inhibitors in soyabean, the exact mechanism involved in the production of this phenomenon still remains obscure The results of the present investigation do not furnish any channel to get any insight into the complexity of this problem in as much as conclusive information as to the concentration of one or more of protease inhibitors and their effects on the physiological responses of the animals in these two pulses, viz., cowpea and tur dhal, is hardly available from literature.

THIRD SERIES OF EXPERIMENTS

Feeding trials with autoclaved cowpea and tur dhal diets each containing 18% protein on nitrogen basis

Data presented in Tables 178 to 180, summarised in Table 187 and statistical analyses of the results given in Table 195 show that animals receiving the autoclaved cowpea diet at 18% protein level on nitrogen basis (Diet J) grow at a significantly higher rate than those receiving the isoproteimic tur dhal diet (Diet K) during the experimental period of 28 days. However, weight gain comparable with that observed on the control diet (Diet L) is not obtained on the diet containing autoclaved cowpea (Diet J).

Protein efficiency values

The data presented in Tables 191 to 193, their summarised values in Table 194 and the results of statistical analyses given in Table 195 reveal that the two pulse protein diets (Diets J and K) do not show any significant difference between them in respect of this efficiency factor.

Blood values

From the summarised data presented in Table 187 and from the statistical analyses of results given in Tables 189 and 190, it is evident that the experimental diets (Diets J and K) do not exert any influence on red cell and haemoglobin concentrations, since animals fed these diets as well as those receiving the control diet (Diet L) show essentially the same values for these formed elements of blood.

Reproduction and lactation studies with raw and autoclaved cowpea and tur dhal diets each containing 18% protein on nitrogen basis

It will be seen from Table 201 that the percentage conception of animals receiving the raw cowpea and raw tur dhal diets (Diets M and N) is comparatively less in

both instances than that of animals maintained on the control diet O, rats receiving diets containing autoclaved cowpea and autoclaved tur dhal (Diets Pand Q respectively) showing no appreciable difference in the percentage conception between themselves or as compared with those receiving the control diet O.

Diets containing on nitrogen basis 18% raw cowpea protein, 18% raw tur dhal protein, 18% casein, 18% autoclaved cowpea protein and 18% autoclaved tur dhal protein (Diets M, N, O, P and Q respectively) do not seem to exert any influence on the litter size (Table 205). A slightly lower birth weight is observed in the case of the new born of animals fed diets containing raw cowpea and raw tur dhal (Diets M and N) as compared with the same of new born of animals maintained on the control diet O. The raw cowpea diet (Diet M) appears to bring about higher birth weight as compared with the tur dhal diet (Diet N). The birth weight of young of animals receiving the raw cowpea diet (Diet M) is comparable with the same of those born of the control animals. As between the new born of animals receiving the autoclaved cowpea (Diet P) and the autoclaved tur dhal (Diet Q) no difference is apparent either between themselves or as compared with control.

Weaning weights of the young of animals receiving the raw pulse diets (Diets M and N) are lower than the same of those of the control animals, weaning weights of the young of animals fed diets M and N showing no appreciable difference between them. As between the animals receiving the autoclaved cowpea and tur dhal diets (Diets P and Q) no noticeable difference is seen in the weaning weights of their young.

From a critical assessment of the overall results obtained during the course of the present investigation, it is evident that both raw tur dhal (*cajanus cajan*) and raw cowpea (*Vigna catjang*) at 10% protein level in the diets on nitrogen basis will not support growth in rats unless these pulses are autoclaved and fed. This observation is essentially in agreement with that reported in the literature (Niyogi *et al.*, 1931; Swaminathan, 1938; Borchers and Ackerson, 1950; Jaffe, 1950; Subba Rao and Subramaniam, 1950; Hirwe and Magar, 1951; Esh and Som, 1952; Sherwood, Weldon and Peterson, 1954; Phansalkar, Patwardhan and Ramachandra, 1957; Elias *et al.*, 1964; Braham *et al.*, 1965; Dako *et al.*, 1966; Devadas *et al.*, 1967; Tara *et al.*, 1972; and Vijayalekshmy *et al.*, 1972).

The poor growth response observed in rats maintained on raw pulse diets (Diets A and B) can hardly be attributed to low food consumption, since the food intakes of animals receiving these diets as well as of those maintained on the control diet were nearly the same.

The significantly higher growth rates observed in animals fed the autoclaved pulse diets positively suggest the presence in these pulses of heat labile antiproteolytic factors as has been reported in the case of several legumes (Bowman, 1944, 46, 48; Kunitz, 1945, 46, 47a, 47b, 48; Borchers et al.,1947; Jaffe, 1950; Sohonie and Ambe;1955; Sohonie and Bhandarkar, 1955;Honavar and Sohonie, 1959a; Sohonie et al., 1959; Honavar et al.,1962 and Jones et al., 1963) inclusive of cowpea and tur dhal (Borchers et al., 1947 and Sohonie and Bhandarkar, 1955).

It has been reported (Vijayaraghavan and Srinivasan, 1953; and Chitre et al., 1956) that the limiting essential amino acids in the proteins of cowpea and tur dhal are methionine and tryptophane. Feeding trials carried out previously by the author of the present thesis for the Masters' degree (Sivaraman, 1969) had shown that methionine and tryptophane supplementation to a synthetic diet containing cowpea protein at 10% level brings about a significantly

higher growth response in rats than that observed either on the control diet containing 10% casein or on the synthetic diet containing 10% isolated tur dhal protein supplemented with methionine and tryptophane. It was observed further that animals maintained on diet containing 10% cowpea protein showed a positive growth response when the diet was supplemented with methionine in the 5th week, tryptophane alone in the 6th week and both methionine and tryptophane in the 7th week, the average weight gains being 14.8g., 6.8g. and 18.4g. respectively. Likewise, animals receiving the synthetic diet containing 10% tur dhal protein also showed a positive growth response when the diet was supplemented with tryptophane in the 5th week, methionine alone in the 6th week and both tryptophane and methionine in the 7th week, the average weekly weight gains being 6.2 g. 7.1 g. and 18.2 g. respectively. The average weekly weight gains of animals receiving the diet containing 10% casein (control diet) during the 5th week, 6th week and 7th week were 5.5 g, 6.0 g. and 5.8g. respectively. The changes in weekly body weight of animals brought about by the withdrawal of methionine and tryptophane, one at a time or both at weekly intervals from the diets (Diets E and F) also indicated that the most limiting

essential amino acid in cowpea protein is methionine and that both methionine and tryptophane are limiting in tur dhal protein (Vide Tables IV and V in Appendix). Data given below, on the amino acid contents of cowpea and tur dhal proteins obtained by chromatographic analysis (Plate I) lend further evidence to support this inference:

Amino acid content in cowpea, tur dhal and their proteins (g./100g.N.)

Amino acids	Cowpea		Tur dhal	
	Flour	Protein	Flour	Protein
Isoleucine	1.1	4.3	0.9	4.0
Leucine	1.3	6.2	0.9	5.3
Lysine	1.1	6.4	0.9	6.3
Methionine	0.2	1.4	0.1	0.8
Phenylalanine	1.2	5.2	1.5	6.7
Threonine	1.0	3.7	1.0	4.5
Valine	1.1	4.5	0.8	3.6

It is interesting to observe that supplementation of autoclaved cowpea and autoclaved tur dhal with methionine and tryptophane further enhances ($p < 0.01$) the growth

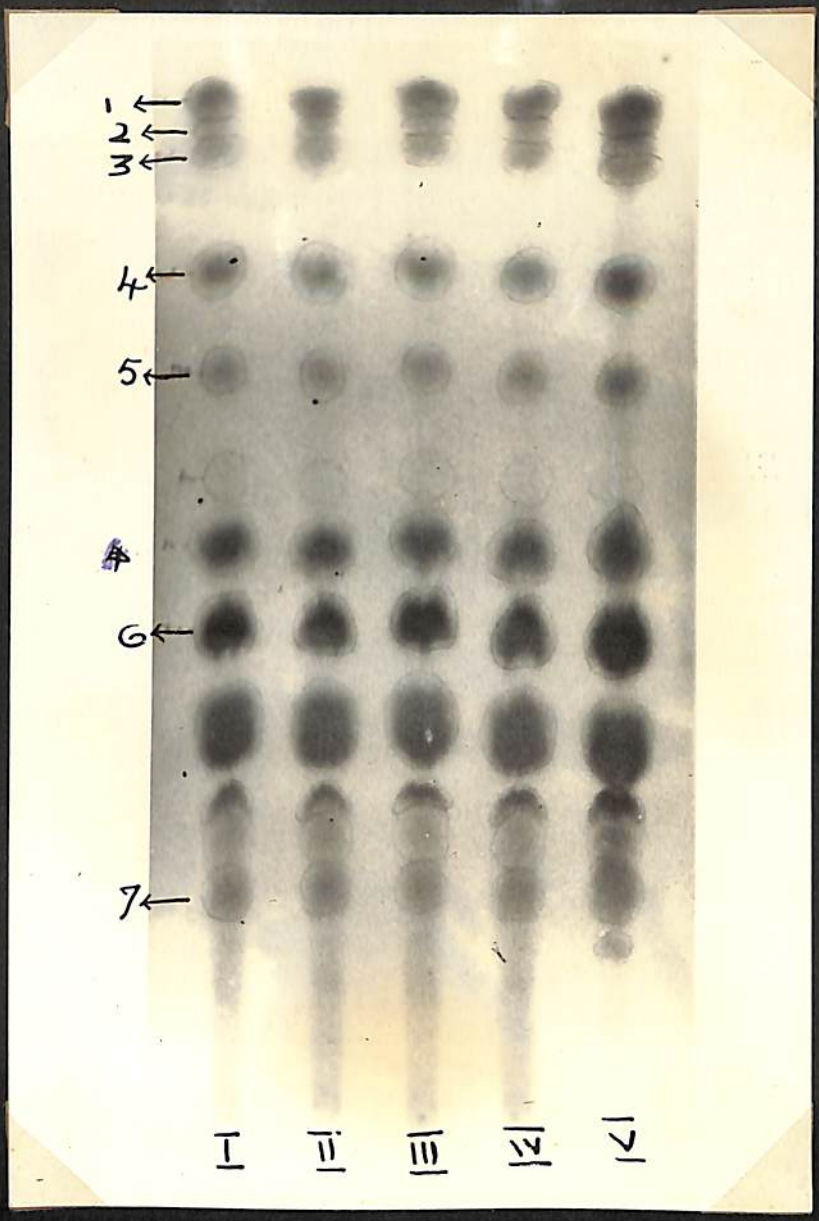


Plate No.I

Paper chromatogram of cowpea and tur dhal--acid hydrolysates

I	II	III	IV	V
Cowpea protein	Cowpea flour	Tur dhal protein	Tur dhal flour	Amino acid Mixture

1. Leucine
2. Isolencine
3. Phenylalanine
4. Valine
5. Methionine
6. Threonine
7. Lysine.

of rats maintained on these diets(Diets H and I). This observation is essentially in keeping with the findings of Devadas et al., (1969), Vijayalekshmy et al. (1972) and Jaffe (1949, 1950) with tur dhal and of Thompson and Simpson (1973) and Sherwood et al. (1954) with cowpea. When autoclaved tur dhal and cowpea were fed at 18% protein level on nitrogen basis (Diets J and K) it was observed that animals receiving the autoclaved tur dhal diet (Diet K) gained weight during the experimental period of 28 days 42 g. only as against 63.0 g. and 73. 9 g. respectively by those fed the diet containing autoclaved cowpea (Diet J) and the control diet (Diet L). It has been reported (Vijayalekshmy et al., 1972; Sohonie and Bhandarkar, 1955) that tur dhal possesses higher trypsin inhibitor activity as compared with cowpea. According to Jaffe (1950[b]) those legumes which have the highest trypsin inhibitor activity ~~ai~~ are also those in which the digestibility as measured in vivo in rats is most improved by cooking. The observation made during the course of the present study in this regard is essentially in keeping with that observed by Jaffe (1950[b])

Autoclaved pulse diets without supplements of amino acids (Diet F, G, H and I) appear to exert beneficial effects

on nitrogen retention, liver protein, and red cell, haemoglobin and plasma protein concentrations - physiological functions specifically dependent on the quality and quantity of dietary protein.

Since the number of animals employed for reproduction and lactation studies was too small, no attempt was made to statistically analyse the data obtained thereon. The results, however, tend to show that the diets used in the present study apparently do not show any appreciable difference in their ability to support these physiological functions.

Considerable literature has accumulated on the concentration, and characterisation and nutritional aspects of protease inhibitors in several legumes (Liener, 1950; 1958, 1962; Borchers, 1965; Rackis, 1965; Birk, 1961; Mickelson and young, 1966; Putzai, 1967; Kunitz, 1945, 1944, 1947, 1948; Birk et al., 1961, 1963; Tauber et al., 1949; Honavar and Sohonie, 1959; Bowman, 1944; Honavar et al., 1962; Sohonie and Bhandarkar, 1959; Sohonie and Ambe, 1955; Borchers et al., 1947) and even in some cereals (Shyamala et al., 1961; Polawowski, 1967; and Shyamala and Lyman, 1964). Beneficial effects brought about on growth response by heat treatment and consequently on account of the

destruction of protease inhibitors totally or mostly. However, according to Liener (1969) (1973) many facets of the subject are still in controversial and unexplained so that a final evaluation of the information at hand is still not possible.

Most of the work on the roles played by protease inhibitors in the nutrition and physiology of the animal organism and the mechanism involved in their activity had been confined to soyabean (Venkat Rao, et al., 1964; Bowman, 1944; Westfall and Hauge, 1948; Liener, 1973 and Bressani and Elias, 1974). Comparatively very little work has been carried out in respect of other legumes, particularly so as applied to tur dhal (Cajanus cajan) and cowpea (Vigna catjang). Besides the work of Esh and Som (1952), Hirwe and Magar (1951), Goyco and Asenjo (1965), Dako (1966), Jaffe (1950), Braham et al. (1965), Hirwe and Magar (1953), Phansalkar et al. (1957) and Basu and Haldar (1939) on tur dhal and of Swaminathan (1937), Niyogi et al. (1932), Jaffe (1949), Richardson (1948), Chaves et al. (1952), Bressani et al. (1961) and Braham et al. (1965) on cowpea hardly any work could be traced from literature in regard to these two pulses of vital importance to a developing country like India. According to Bressani (1973), supplying adequate amounts of high quality protein to the increasing population in developing countries

is not an easy endevour and the time for the nutritional and agronomic improvement has now arrived-foods that have been chosen as the natural protein supplements to cereal grains since neolithic times. The applications of the beneficial results obtained during the course of the present investigation in regard to these two pulses viz., cowpea and tur dhal, on autoclaving and on supplementation with the limiting essential amino acids methionine and tryptophane, are therefore to be reckoned as significant and of paramount importance in feeding practice from point of view of national health and wealth. In fact that it is so has been indicated by Swaminathan (1971).

SUMMARY

SUMMARY

Three series of feeding trials were carried out using growing albino rats as experimental subjects during the present investigation in order to assess (1) the comparative effects of feeding raw and autoclaved cowpea and raw and autoclaved tur dhal incorporated in the diet each at 10% protein level on nitrogen basis on specific physiological functions such as growth, nitrogen balance, blood formation, liver fat, liver protein and liver and serum enzymes (2) the relative merits of these diets on feeding on the various physiological functions on supplementation with methionine and tryptophane and (3) the improvements brought about in respect of the various physiological functions when autoclaved pulses are incorporated in the diets at 18% protein level on nitrogen basis and fed. These experiments were performed in continuation of the work carried out by the author for the M.Sc. degree on the nutritive values of the two pulses, viz., tur dhal and cowpea. The salient observations made during the course of the three series of experiments carried out during the course of the present investigation and the obviously important inferences drawn from the results obtained are given below, series wise:-

FIRST SERIES OF EXPERIMENTS

(1) Diets containing raw cowpea and raw tur dhal each containing 10% protein on nitrogen basis do not support somatic growth in rats.

(2) Both autoclaved cowpea and autoclaved tur dhal diets each containing 10% protein on nitrogen basis promote growth of rats, the average gain in weight in both instances being essentially the same.

(3) Autoclaved cowpea and autoclaved tur dhal diets are inferior to the control diet in promoting growth response.

(4) Growth rate is not influenced by food consumption as little variation is shown in this respect between the animals fed the different diets.

(5) Autoclaved cowpea and autoclaved tur dhal diets give significantly higher protein efficiency values than the corresponding raw pulse diets, both these registering essentially identical values in this respect, but significantly lower values as compared with the control diet.

(6) In regard to nitrogen retention the results show the same trend as protein efficiency values.

(7) Digestibility coefficients of nutrients in the autoclaved cowpea and tur dhal diets are significantly higher than of those in the respective raw pulse diets but less so as compared with the control diet, the raw pulse diets showing no significant difference between them.

(8) The diets used in the present study do not show any significant difference between them in their ability to support red cell, haemoglobin and plasma protein concentrations.

(9) Glutamic oxalo acetic transaminase and glutamic pyruvic transaminase concentrations in serum and liver are not significantly influenced by any one of the diets used in the present study, although on the raw cowpea diet and on the raw tur dhal diet comparatively lower values for glutamic pyruvic transaminase are obtained.

(10) Liver glycogen is not significantly influenced by any of the diets used in the present study.

(11) Diets containing raw cowpea and raw tur dhal bring about on feeding significantly higher liver fat content as compared with the control diet and the autoclaved tur dhal diet. As between the autoclaved

pulse diets no significant difference is observed.

(12) As regards the liver protein content no significant difference is discernible between the diets used in the present study.

(13) The autoclaved pulse diets increase significantly the weight of liver, kidney and heart as compared with raw pulse diets.

(14) The raw cowpea and raw tur dhal diets bring about on feeding significantly higher caecal weight in rats as compared with the control diet, the raw tur dhal diet bringing about significantly higher caecal weights than the autoclaved tur dhal diet.

(15) On the autoclaved pulse diets, significantly lower weights for pancreas are obtained as compared with the raw pulse diets. While no significant difference is observed in pancreatic weights between animals fed raw cowpea diet and autoclaved cowpea diet, significantly higher pancreatic weight is observed in the case of animals maintained on the raw tur dhal diet as compared with the diet containing autoclaved tur dhal.

SECOND SERIES OF EXPERIMENTS

(1) Diets containing raw cowpea and raw tur dhal both supplemented with methionine and tryptophane promote growth in rats in contrast with the results observed in the first series of experiments with raw cowpea and raw tur dhal without supplementation with these limiting amino acids. Significantly higher growth rate is obtained in the present series of experiments, with diet containing tur dhal as compared with that containing cowpea.

(2) As regards the amino acid supplemented autoclaved pulse diets, both promote significantly higher growth, diet containing autoclaved tur dhal exerting significantly higher influence than diet containing autoclaved cowpea.

(3) Autoclaved pulse diets supplemented with the limiting amino acids, methionine and tryptophane promote significantly better growth in rats than the control diet.

(4) Supplementation of diets containing raw or autoclaved cowpea and raw or autoclaved tur dhal, with methionine

and tryptophane significantly enhances their protein efficiency values.

(5) The autoclaved cowpea and tur dhal diets supplemented with methionine and tryptophane register significantly higher protein efficiency values as compared with the control diet, the amino acid supplemented tur dhal diet signalling and significantly higher value in this regard than the amino acid supplemented autoclaved cowpea diet.

(6) Autoclaving cowpea and tur dhal brings about with or without methionine and tryptophane supplementation a higher nitrogen retention in rats than the raw pulse diets, maximum nitrogen retention being obtained in the control diet.

(7) As between the amino acid supplemented raw and autoclaved cowpea diets on one hand and the amino acid supplemented raw and autoclaved tur dhal diets on the other, no significant difference is observed in nitrogen retention.

(8) Supplementation with methionine and tryptophane significantly enhances protein digestibility in diets irrespective of the fact, whether the diets contain raw or autoclaved cowpea or raw or autoclaved tur dhal.

(9) Supplementation with methionine and tryptophane does not influence the digestibility of fat while carbohydrate digestibility is seen to be significantly increased in the case of the amino acid supplemented raw cowpea diet as compared with that in the amino acid supplemented tur dhal diet.

(10) Supplementation with methionine and tryptophane does not bring about any beneficial effect on the digestibility of carbohydrate either in the case of autoclaved cowpea diet or in the case of autoclaved tur dhal diet.

(11) As regards red cell and haemoglobin concentrations, no significant difference is observed between the animals maintained on the various diets. In respect of plasma protein concentration, however, a significantly higher concentration of plasma protein is observed in animals receiving the raw cowpea diet supplemented with methionine and tryptophane as compared with those maintained on the amino acid supplemented raw tur dhal diet.

(12) In respect of maintenance of glutamic oxalo acetic transaminase and glutamic pyruvic transaminase levels in serum and liver and liver glycogen content, te

the diets used in the present study do not show any significant difference between them.

(13) On raw tur dhal diet supplemented with methionine and tryptophane, significantly higher liver fat content is observed as compared with that obtained on the raw cowpea diet supplemented with these amino acids.

(14) As regards liver protein no significant difference attributable to the diet is observed.

(15) A significantly higher increase in the weight of livers of rats maintained on the diet containing raw cowpea supplemented with methionine and tryptophane is discernible as compared with those of animals fed the tur dhal diet supplemented with the same amino acids.

(16) The caecae with contents, of rats maintained on diets containing raw tur dhal supplemented with methionine and tryptophane show significantly higher weights as compared with those of animals fed the amino acids supplemented autoclaved cowpea and autoclaved tur dhal diets showing no significant difference in this respect.

(17) Significantly higher pancreatic weights are observed in the case of rats maintained on diets containing raw cowpea supplemented with methionine and tryptophane as compared with the same of animals receiving an isoproteimic tur dhal diet. As between the amino acid aupplemented autoclaved cowpea and tur dhal diets, there is no significant difference.

THIRD SERIES OF EXPERIMENTS

(1) Autoclaved cowpea diet at 18% protein level on nitrogen basis promotes a significantly higher growth response than an isoproteimic tur dhal diet.

(2) As regards protein efficiency, the two pulse protein diets do not show any significant difference between them.

(3) Red cell and haemoglobin concentrations are not seen influenced by either of the diets.

(4) The limited data obtained during the course of the present study do not indicate any appreciable difference between the diets in their ability to support physiological functions such as reproduction and lactation.

The significance of the above influences is discussed briefly.

REFERENCES

Acharya, B.N., Niyogi, S.P. and Patwardhan, V.N. (1942). Indian J.med.Res., 30, 73.

Adolf, W.H. (1944), Science, 100, 1.

Adolf, W.H., Shawwar, E.I. and Halaby, S.K. (1955), Food. Res., 20, 31.

Allison, J.B. (1950), "Report on amino acid content and the nutritive role of six protein sources". Bureau of Biol.Res. Rutgers Univ., New Brunswick, N.J.

Allison, J.B., Chow, B.F., White, J.I. and Roth, J.S. (1944). J. Biol. Chem., 171, 91.

Aykroyd, W.R. and Krishnan, B.G. (1937), Indian J.med.Res., 25, 299.

REFERENCES

Allison, J.B. (1955). Physiol. Rev. 35, 664.

Altschul, A.M., Yatsu, L.Y., Ory, R.L. and Engleman, E.M. (1956), Ann. Rev. Plant Physiol., 17, 113.

Almquist, H.J., Mecchi, E., Kratzer, F.H. and Grau, C.R. (1942). J.Nutrition, 24, 385.

Balasubrahmanian, C.S., Lily, G., Rani, G.S. and Rao, K.P. (1955), Indian J.med.Res., 43, 255.

Balasubrahmanian, S.C., Ramachandran, N., Viswanatha, T. and De, S.S. (1952), Indian J.med. Res., 40, 219.

Balasubrahmanian, S.C., Ramachandran, N., Viswanatham, T. and De, S.S. (1952), Indian J. med. Res., 40, 173.

Basu, K.P. and Basak, M.N. (1937), Indian J.med.Res. 24, 1033.

Bergmeyer, H.U. (1955), Methods of Enzymatic Analysis, Academic Press, New York.

REFERENCES

Acharya,B.N., Niyogi, S.P. and Patwardhan, V.N. (1942), Indian J.med.Res., 30, 73.

Adolf, W.H. (1944), Science, 100, 1.

Adolf, W.H., Shammar, E.I. and Halaby, S.H. (1955), Food. Res., 20, 31.

Allison, J.B. (1950), "Report on amino acid content and the nutritive role of six protein sources". Bureau of Biol.Res. Rutgers Univ., New Brunswick,N.J.

Allison,J.B., Chow, B.F., White,J.I. and Roth, J.S. (1949), J. Biol. Chem., 171, 91.

Aykroyd, W.R. and Krishnan, B.G. (1937), Indian J.med.Res., 24, 1093.

Allison, J.B. (1955), Physiol. Rev. 35, 664.

Altschul, A.m., Yatse, L.Y., Ory, R.L. and Engleman, E.M. (1966), Ann. Rev. Plant Physiol., 17, 113.

Almquist, H.J., Mecchi, E., Kratzer, F.H. and Grau, C.R. (1942), J.Nutrition, 24, 385.

Balasubrahmanian, C.S., Lily, G., Mani, G.S. and Basu, K.P. (1955), Indian J.med.Res., 43,255.

Balasubrahmanian, S.C., Ramachandran, M., Viswanatha, T. and De, S.S. (1952), Indian J.med. Res., 40, 219.

Balasubrahmaniam, S.C., Ramachandran, M., Viswanathan, T. and De, S.S. (1952), Indian J. med. Res., 40, 173.

Basu, K.P. and Basak, M.N.(1937), Indian J.med.Res.24,1043.

Bergmeyeyer, H.U.(1965), Methods of Enzymatic Analysis, Academic Press, Newyork.

Basu, K.P., Basak, M.N. and De, H.N. (1941), Indian J.med. Res., 29, 105.

Basu, K.P. and Basak, M.N. (1937) Indian J.med.Res., 24, 1043.

Basu, K.P. and Mukherji, S. (1936), Indian J,med.Res., 23, 777.

Basu, K.P.1946),"Studies on protein, fat and mineral metabolism in Indians" spl. Report No.15: Indian Research Fund Association, New, Delhi.

Basu, K.P. and Gupta, K.J. (1939), J. Indian Chem. Soc., 16, 209.

Basu, K.P. and De, H.N. (1938), Indian of med.Res., 26,177.

Basu, K.P. and Hardar, M.K. (1939), J.Indian Chem.Soc., 16, 289.

Basu, K.P. and Haldar, M.K. (1939), J. Indian Chem. Soc., 16, 189.

Beach, E.F., Munks, B., Robinson,A. and Macy,I.G. (1943) J.Amer.Dietet.Assoc., 19, 570.

Beach, E.F., Munks, B., Robinson, (1943) J.Biol.Chem., 148, 431.

Block, R.J. and Bolling, D. (1944) J.Amer.Dietet.Assoc., 20, 69.

Block, R.J. and Mitchell, H.W. (1946), Nutrition Abstr. and Rev., 16, 249.

Block, R.J. and Bolling, D. (1951), The amino acid composition of proteins and foods, C.C.Thomas, Springfield, Illinois, U.S.A.

Bell, J.M., Graham, V.E., Gibson, D.L. and Lawton, W.C. (1954) Canad of Technol., 32,55.

Bleeker, Th.W. and Wostmann, B.S.J. (1954) Conserva, 2,33.

Block, R.J. and Bolling, D. (1944), Arch.Biochem., 3, 217.

Block, R.J. and Bolling, D.(1944), J.Amer.Dietet.Assoc., 20, 69.

Barnes, R.H.,Maach, J.E., Kinghts, M.J. and Burr, G.O. (1945), Cereal Chem., 22, 273.

Beach, E.F., Marks, B., Robinson, A. and Macy, I.G.(1943), of Amer.Dietet.Assoc., 19, 570.

Beach, E.F., Munks, B. and Robinson, A. (1943), of Biolo. chem., 148.

Beeveridge, J.M.R. (1947), J.Fish.Res.Board can., 7, 51.

Baumgarten, W., Mather, A.N. and stone, L. (1946), Cereal Chem., 23, 135.

Balliete, R.F., De-Caprio, P. and Sevringhaus, E.L. (1950), J.Amer. Dietet.Assoc., 43, 255.

Block, R.J. and Weiss, K.W. (1956), Amino acid hand book, Carles, C. Thomas, Spring field, Illenois.

Baptist, N.G. (1954), Brit. of Nutrition, 8, 218.

Baptist, N.G. (1956), Ceylon, J.Sci., 2, 15.

Becker, D.E., Adams, C.R., Terrill, S.W. and Meade, R.J. (1953), J. Animal Sci., 12, 107.

Beeson, W.M., Lehrer, W.P., and Woods, E. (1947), J. Nutrition 34, 587.

Borchers, R. (1965), J. Federation Proc., 24, 1494.

Birk, Y., Gertler, A. and Khalef, S. (1963), Biochem.J., 87, 281.

Birk, Y. (1961) Biochim.Biophys.Acta., 54, 378.

Birk, Y. (1968), Nutritional significance of protease inhibitors from plan sources, in "Chemistry & Pharmacology and Clinical applications of protease inhibitors (Eds.A.N.Back & E.F.Manmen) Ann.N.Y.Acad.Sci.146, 388.

Back, N. and Mammen, E.F. (1968), Ann. N.Y.Acad.Sci., 146, 361.

Barnes, R.H., Fiala, G. and Kwong, E. (1962), J.Nutrition, 77, 278.

Borchers, R. (1962), J.Nutrition, 77, 309.

Borchers, R. and Ackerson, C.W. (1950), J.Nutrition, 41,339.

Barnes, R.H. and Kwong, E. (1965), J.Nutrition, 86, 245.

Borchers, R., Ackerson, C.W. and Sandstedt, R.M.L. (1947), Arch.Biochem.Biophys., 12, 367.

Barnes, R.H., Fiala, G. and Kwong, E. (1965), J.Nutrition, 85, 127.

Borchers, R. (1962 a), J.Nutrition, 77, 309.

Bouthilet, R.J., Hunter, W.L., Luhman, A., Ambrose, D. and Lepkovsky, S. (1950), Poultry Science, 29, 837.

Bressani, R., Valiente, A.T. and Tajida, G. (1962), J.Food Sci., 27, 394.

Bressani, R., Elias, L.G. and Braham, J.E. (1968), Arch. Latinoamer. Nutri 19, 129.

Bell, J.M. and Young, C.G. (1970), Can.J.Anim.Sci. 50,219.

Borchers, R. (1962), J.Nutrition, 77, 309.

Braham, J.E., Vela, R.M., Bressani, R. and Jarquin, R. (1965), Arch.Venez.Nutr. 15, 19.

Baptist, N.G. (1954), Brit.J.Nutr., 8, 218.

Bressani, R., Mentes, J. and Crimshand, N.S. (1960), Arch.Venezol.Nutr.,10, 71.

Bressani, R., Elias, L.G. and Valiente, A.T. (1963), Brit.J. Nutr., 17, 69.

Bressani, R., Elias, L.G. and Navarrete, D. (1961), J.Food Sci., 26, 525.

Bressani, R., Wilson, D.M., Viteri, F., Mosovich, L. and Alvarado, J. (1971), Arch.Latinoamer.Nutr., 21, 347.

Bressani, R. (1973), In "legumes in human diets and how they might be improved", Nutritional Improvement of Food Legumes by breeding. Procedings of a symposium sponsored by PAG, FAO, Rome and PAG statement 22. Ed. by Dr. Max Milner, PAG group of the United Nations system, New York.

Bressani, R., Elias, L.G. and Nevarette, D. (1961), J.Food Sci., 26, 525.

Braham, J.E., Vela, R.M., Bressani, R. and Jarquin, R. (1965), Arch.Venezol.Nutr., 15, 19.

Bressani, R. and Elias, L.G. (1974), "Legume foods" in new protein foods. Ed. A.M. Altschul, Academic press, New York.

Bowman, D.E. (1948), Arch.Biochem.Biophys., 16, 109.

Bowman, D.E. (1946), Proc.Soc.Exptl.Biol.Med., 63, 547.

Bowman, D. E. (1944), Proc. Soc. Exptl. Biol. Med., 57, 139.

Borchers, R., Ackerson, C.W. and Sandstedt. (1947), Arch.Biochem.Biophys.,13, 291.

Borchers, R., Ackerson, C.W. and Kimmett, L. (1947), Arch. Biochem. Biophys., 13, 291.

Chow, B.F., Allison, J.B. and White, J. (1948), J.Nutrition, 36, 231.

Chow, B.F. (1950), Protein and amino acid requirements of mammels, edited by A.A.Albanese, P.94, Academic Press, New York.

Campbell, R.M. and Kosterlitz, H.W. (1948), J.physiol., 107, 383.

Cannon, P.R., Humphreys, E.M., Wissler, R.W. and Frazier, L. (1944), J.Clin.Invest., 23,601.

Cannon, P.R. (1945), Advances in protein chem., 2, 135.

Chow, B.F., Allison, J.B. and White, J. (1948), J.Nutrition, 36, 231.

Cox and Mueller, (1944), J.Clin.Invest., 23, 875.

Chandran, K. and Damodaran, M. (1951), Biochem.J., 49, 393.

Chibnall, A.C., Rees, M.W. and Williams, E.F. (1943), Biochem.J., 37, 372.

Csonka, F.A. (1937), J.Biolcchem., 118, 147.

Csonka, F.A. (1941), Cereal Chem., 18, 523.

Csonka, F.A. (1939), J.Agri.Res., 59, 765.

Chick, H. (1942), Lancet,, 242, 405.

Clark, H.E., Hooper, A.S. and McCord, M.L. (1955), J.Nutrition, 55, 63.

Crosnier, R. and Margueritte, (1951), Ann.Hyg.Pub., Daris., 29,76.

Chen, C.Y. and Wang, T.C. (1943), Chinese nutrition Bull., 3, 29.

Carrol, R.W., Hensley, G.W. and Graham, W.R.Jr. (1952), Science,115, 36.

Carrol, R.W., Hensley,

Chang, Yet-oy and Chao, N. (1969), J.Agr.Food.Chem., 17, 48.

Chaves, N., ReoBarros, M.M., Madruga, I., Lapa, M.A.G., Freitas, C.P., Delima, J.A.L. and DaCosta, L.P. (1962), Rev.Brazil,Med., 19, 385.

Chaves, N., Teodosia, N.R., Gomezde Matos, Jr.A., Lima, C.A. and DeAlmeida, J.L. (1952), Rev.Brazil.Med., 9, 603.

Chitre, R.G., Desai, D.B., Ganapathi, S., Kumana, J.S. and Vallury, S.M. (1956), Indian J.med.Res., 44, 573.

P P.R.

Damodaran, M. and Vijayaraghavan, T.K. (1943), Curr.Sci., 12, 115.

Dju, M.Y., Baur, L.S. and Filer, L.J.Jr., (1957), J.Nutrition, 63, 115.

Deshpande, P.D., Harper, A.E., Quirosperez, F. and Elvehjem, C.A. (1955), J.Nutrition, 57, 415.

Dunn, M.S. (1947)Food Teeh., 1, 269.

Dunn, M.S., Camien, M.N., Eiduson, S.L. and Malini, R.R. (1956), J.Nutrition, 39, 177.

Duel, H.J., Hrubetz, M.C., Johnston, C.H., Winzler, R.J., Geiger, E.L. and Schnakenberg, G. (1946), J.Nutrition 31,175.

Dju, M.Y., Baur, L.S. and Filer, L.J., Jr., (1957), J.Nutrition, 63, 115.

Danielson, C.E. and Lis, H. (1952)Acta.Chem.Scand., 6, 139.

Danielson, C.E. (1950) Acta.Chem. Scand., 4,762.

Danielson, C.E. (1949), Biochem. J., 44, 39.

Desai, B.L.M., Kurian, S., Daniel, V.A., Narayanaswami, D., Swaminathan, M. and Parpia, H.A.B. (1970),Nutr. Reports.Int., 1, 113.

Daniel, V.A., Desai, B.L.M., Naryanaswami, D., Kurian, S., Swaminathan, M. and Parpia, H.A.B. (1970), Nutr.Rep.Int., 1, 169.

Devadas, R.P., Girijabai, R. and Snehalatha, N. (1967), J.Nutr.Dietet., 4, 300.

Dako, D.Y. (1966), Thesis, Landwirtsch, Fak, Justus, Leibig, Univ,, Giessen, Germany.

Daniel, V.A., Rao, S.V., Swaminathan, M. and Parpia, H.A.B. (1968), J.Nutr.Dietet., 6, 15.

Daniel, V.A., Rao, S.V., Swaminathan, M. and Parpia, H.A.B. (1969), J.Nutr.Dietet., 6, 15.

De, H.N., Khan, S.A., Mallick, N.I. and Islam, A. (1969), Sci.Res., 6,133.

Daniel, V.A., Desai, B.L.M., VenkataRao, S., Swaminathan, M. and Parpia, H.A.B. (1970), Plant Food human nutri, 2, 1.

Desai, B.L.M., Harikaran, K., Paul Jayara, A., Venkat Rao, S. and Swaminathan, M. (1968), J.Nutr.Dietet., 5, 45.

Daniel, V.A., Desai, B.L.M., Subramania Raj Urs, T.S., Venkat Rao, S., Swaminathan, M. and Parpia, H.A.B. (1968), J.Nutr.Dietet., 5, 283.

Esh, G.C. and Som, J.M. (1955), Proc.Nat.Inst.Sci.India., 21, B, 68.

Esh, G.C. and Som J.M. (1952), Indian J.Physiology, an d all.sci., 6, 61.

Esh, G.C. and Som, J.M. (1953), Indian J. Physiology and all.Sci., 7, 188.

Evans, R.J. and McGinnis, J. (1946), J.Nutrition, 31, 449.

Everson, G. and Hackert, A. (1944), J.Amer.Dietet,Assoc., 20, 81.

Evans, R.J. and McGinnis, J. (1948), J.Nutrition 35, 477.

Elias, L.G., Golinders, R. and Bressani, R. (1964), J.Food. Sci., 29, 118.

Esselbaugh, N.C., Murray, H.C., Hardie, L.W. and Hard, M.M. (1952), J.Nutrition, 46, 109.

Fritz, J.C., Kramke, E.H. and Reed, C.A. (1947), Poultry Sci., 26, 657.

Forbes, R.M. and Yohé, M. (1955), J.Nutrition, 55. 493.

F.A.O.World Fish abstract (1952), 3, (Nov3), 41.

Frey, K.G. (1952), cereal Chem., 29, 77.

Flynn, L.M., Zuber, M.S., Leweke, D.H.A., Grainger, R.B. and Hogan, A.G. (1954), Cereal Chem., 31, 217.

Gyco, J.A. and Asenjo, C.F. (1965), J. Nutrition, 85, 52

Grewe, E., and Laclere, J.A. (1945), Cereal Chem., 20, 434.

Gordhan, H.H., Levine, S.Z., Wheatly, M.A. and Marples, E. (1937), Amer.J.Diseases children, 54, 130.

Grewe, E. and Leclare, J.A. (1945), Cereal Chem., 20. 434.

Grau, C.R. (1946), J.Nutrition, 32, 303.

Giral, J.and Echegoyen, M.B. (1949), Ciencia (Mex), 9, 300.

Groschke, A.C., Anderson, J.O. and Briggs, G.M. (1948), Proc.Soc.Expt.Biol., and Med., 68, 564.

Henry, K.M., Cormack, R.M. and Kosterlitz, H.W. (1961), Brit.J.Nutrition, 15, 199.

Horn, M.J. and Whipple, G.H. (1939), J.Expt.Med., 19, 315.

Halman, Mahoney, E.B. and Whipple, G.H. (1934), J.Exp. Med., 59, 251.

Harper, A.E., Winger, M.E., Bentow, D.A. and Elvehjem, C.A. (1955), J.Nutrition, 56, 187.

Hogland, R., Ellis, N.R., Hawkins, C.G. and Snider, G.G. (1947), J.Nutrition 34, 43.

Hodson, A.Z. and Kueger, G.M. (1946), Arch.Biochem., 10, 55.

Henry, K.M. and Kon, S.K. (1946), J.Dairy Res., 14, 330.

Hess, W.C., Kramke, E.H., Fritz, J.C. and Howard, H.W. (1948), Proc.Soc.Exptl.Biol., and Med., 67, 552.

Hawley, E.E., Murlin, J.R., Nasset, E.S. and Zymanki, T.A. (1948), J.Nutrition, 36, 153.

Harte, R.A. (1945), Science, 102, 563.

Ham, W.E., Sandstedt, R.M. and Mussehl, F.E. (1945), J.Biol.Chem., 161, 635.

Hirwe, R.N. and Magar, N.G. (1951), Curr.Sci., 20, 40.

Hegsted, D.M. and Worcester, J. (1947), J.Nutrition, 33, 685.

Hove, E.L., Carpenter, L.E. and Harrel, C.G. (1945), Cereal Chem. 22, 287.

Hove, E.L. and Harrel, C.G. (1943), Cereal Chem., 20, 141.

Holmes, P. (1953), Australian J.Exptl.Med.Sci., 31, 595.

Hayward, J.W., Steenbock, H. and Bohstedt, G. (1936), J.Nutrition, 11, 219.

Hayward, J.W. and Hafner, F.H. (1941), Poultry science, 20, 139.

Hisateru Mitsuda and Kyoden Yasumota (1974), In "Newer protein foods",(Ed) Aaron, M. Altschul, Academic press, New York.

Hutchinson, J.B. and Martin, H.F. (1955), J. Agri.Sci., 45, 419.

Howe, E.E., Jansen, G.R. and Gilfillan, E.W. (1965), Amer. J.Clin.Nutr., 16, 315.

Howe, E.E., Jansan, G.R. and Arsun, M.L. (1961), Amer.J. Clin.Nutr., 20, 1134.

Hirwe, R. and Magar, N.G. (1953), Indian J.med.Res., 41, 191.

Hanafy, M.M., Seddik, Y. and Aref, M.K. (1970), J.Sci. Food Agri., 21, 16.

Harper, A.E., Winge, M.E., Beton, D.A., and Elvehjem, C.A. (1955), J.Nutr., 56, 187.

Howe, E.E., Jansen, G.R. and Anson, M.L. (1967), Amer. J.Clin.Nutr., 20, 1134.

Hansen, J.D.L., Schendel, H.E., Wilkins, A. and Brock, J.F. (1960), Pediatrics, 25, 258.

Hanefy, M.M., Seddik, Y. and Aref, M.K. (1970), J.Sci. Food Agr., 21, 9.

Hanefy, M.M., Seddik, Y. and Aref, M.K. (1970), J.Sci. Food Agr., 21, 13.

Honavar, P.M. and Sohonie, K. (1959), J.Sci.Ind.Res. (India), 18C, 202.

Honavar, P.M., Shih, C.V. and Liener, I.E. (1962), J.Nutrition, 77, 109.

Hanumantha Rao, k. and Subramanian, N. (1970), J. Food Science and Tech., 7, 31

Irvin, E. Liener (1958) processed plant protein food stuffs (Ed) Aaron, M.Altschul, Academic press, New York.

Jones, D.B. and Widness, K.D. (1946) J.Nutrition, 31, 675.

Jaffe, W.G. (1950), Arch.Venezolanos.Nutr. 1, 107.

Jaffe, W.G. (1945), Proc.Soc.Exptl.Biol.med., 71, 398.

Jaffe, W.G. (1949), Experimentia, 5, 81.

Jones, D.B. and Murphy, J.C. (1924) J.Biol.Chem., 59, 243.

Jaffe, W.G. (1961), Arztl.Forech, 12, 1022.

Jaffe, W.G. (1950 a), Acta Cient., venezolana, 1, 62.

Jaffe, W.G. (1950 b), proc.Soc.Exptl.Biol.Med., 75, 219.

Jansen, G.R.(1962), J.Nutr.Suppl., 1,76, Part II.

Jones, D.B., Frinks, A.J. and Gusdorff, C.E.F. (1922), J.Biol.Chem., 51, 103.

Joshi, S., Master, F. and Magar, N.G. (1953), Indian J.med. Res., 41, 431.

Jaffe, W.G. and Hanning, K. (1965), Arch.Biochem.Biophys., 109, 80.

Jenneskens, P.J. (1969), Cereal Sci.today, P 186.

Jaffe, W.G. (1949), Proc.Soc.Exp. med.Biol., 7, 398.

Jaffe, W.G. (1950), Arch.Venezol.Nutr. 1, 107.

Jones, G., Moore, S.and Stein, W.H. (1963), Biochemistry, 2, 66.

Kraybill, H.R. (1948) Protein and amino acids in Nutrition, Reinhold publishing corporation, New York.

Kelley, E.G. and Baum, R.R. (1953) J.Agri.Food.Chem, 1,680.

Kuppuswami, S., Srinivasan, M., and subramaniam, V. (1958), Proteins in Foods, spl.Rep.Ser.100:33, I.C.M.R., New Delhi.

Kik, M.C. (1941),Cereal chem., 18, 349

Kik, M.C.(1940) Cereal chem., 17/473

Kik, M.C. (1940), J.Agri.Food.Chem 2, 1179.

Kik, M.C.(1942), University of Arakansas, Experimental Station Bulletin No.416,16.

Klose, A.A., Graeaves, J.D. and Fevold, H.L. (1948), Science, 108, 88.

Kothari, K. and Sohonie, J. (1960), J.Sci.Industr.Res., 19, C, 16.

Kunitz (1945), Science, 101, 668.

Kunitz (1946), J.Gen.Physiol., 29, 149.

Kunitz (1947 a), J.Gen.Physiol., 30, 291.

Kunitz (1947 b), J.Gen.Physiol, 30, 311.

Kunitz (1948), J.Gen.Physiol., 32, 241.

Kakade, M.L. and Evans, R.J.(1965), J.Agr.Food.Chem., 13, 450.

Krishnamoorthi, K., Taskar, P.K., Ramakrishnan, T.N., Rajagopalan, R., Swaminathan. M. and Subramaniam, V. (1958), Ann. Biochem.Exptl.Med., 18, 153.

Kakade, M.L. and Evans. R.J. (1966), Can.J.Biochem.Physiol., 44, 648.

Kakade, M.L. and Evans, R.J. (1966), J.Food.Sci., 31, 781.

King, K.W. (1964), Econ.Botany, 18, 311.

Litwack, G., William, J.N., Jr., Fattaparker, P.I., Chen, L. and Elvehjem, C.A. (1953), J.Nutrition, 49, 579.

LeRrer, W.P., Woods,E. and Beeson, W.M.(1948), Food Res., 33, 369.

Lepoz-Matas, A., and Fellers, C.R. (1948), Food Res., 13, 387.

Lugg, J.W.J.and Weller, R.A. (1944), Australian J.Exptl. Biol.med.Sci., 22, 149.

Lewis, J.H. and Tayler, F.H.L. (1947), Proc.Soc.Exptl. Biol.Med., 64, 85.

Liener, I.E. and Hill, E.G. (1953) J.Nutrition, 49, 609.

Liener, I.E. (1950), Cereal.Chem., 8, 162.

Liener, I.E. (1955), Processed plant protein foods. C Academic press. New York.

Liener, E.E. (1962), Am.J.Chin.Nutr., 11, 281.

Laskowski, M. and Laskowski, M. Jr. (1954), Advan.protein, Chem., 9, 203.

Liener, I.E. (1958), "Effect of heat in plant proteins." In processed plant food stuffs, Ed. A.M.Altschull, Academic press, New York.

Liener, I.E., Fevold, H.L. (1949), Arch.Biochem. Biophys., 21, 395.

Liener, I.E. (1973), Antitryptic and other nutritional factors in legumes. In "Nutritional improvement of food legumes why breeding", proceedings of a Symposium sponsored by PAG, held at F.A.O., Rome and PAG statement 22., Ed. Dr.Maxmilner, PAG group of the United Nations System, New York.

Liener, I.E. (1969), Toxic constituents of plant food stuffs, Academic Press, N.Y.

Mendel, L.B. and Fine, M.S. (1912), J.Biol.Chem., 10, 303.

Madden, S.C., Winslow, Howland and Whipple (1937), J.Exptl. med., 65, 431.

McNaught, Scot, Woods and Whipple (1936), J.Exptl.med., 63, 277.

Melnick, D. and Cowgill, G.R. (1937), J.Nutrition, 13, 401.

Maramatsu and Ashinda (1962), Aric.and Biol.Chem., 26 (1), 25.

Mariani, A., Spadoni, M.A. and Tomassi, G. (1963), Nature, 199, 378.

Mitchell, H.H. and Block, R.J. (1946), J.Biol.Chem., 163, 599.

Millers, R. and Fellers, C.R. (1948), J.Amer.Dietet. Assoc., 24, 1057.

Mitchell, H.H. and Beadles, J.R. (1950), J.Nutrition 40, 25.

Mitchell, H.H. and Carman, G.G., (1926), J.Biol.Chem., 68, 183.

Muller, A.J. and Cox, W.H. (1947), J.Nutrition 34, 285.

Mitra, K. and Mitra, H.C. (1942), Indian J.med.Res., 30, 423.

Mitra, K. and Varma, S.H. (1947), Indian J.med,Res., 35, 23.

Mitchell, H. H. and Beadles, J.R. (1950), J. nutrition, 40, 25.

Mitchell, H.H. and carman, G.G. (1926), J.Biol.Chem,, 60, 613.

MacDonald, A.J. and Bose, S. (1945), Indian J.Med.Res. 30, 255.

MacDonald, A.J. and Bose, S. (1945), Indian J.med.Res., 33,77.

Master, F. and Magar, N.G. (1954), Indian J.med.Res., 42, 509.

Mahalanobis, S.K. and Roy, R.N. (1953), Indian J.Physiol and B.H.Sci,, 6, 120.

McCarrisson,R.(1928), Indian J.Med.Res., 15,915.

McEnlory, L.W., Clandinin, D.R., Lobay, W. and Petty Bridge, S.I. (1949), J.Nutrition, 37, 329.

Mitchell, H.H. and smuts, D.B. (1932), J.Biol.Chem., 95, 263.

Mitra. K. and Varma, S.I. (1948), Indian J.med.Res., 36, 261.

McCollum,E.V. (1945), Science, 102, 181.

Mohan, J.H. and commcon, R.H. (1950) Science. Agri. 30, 43.

Murray, H.C. (1948), J.Nutrition, 35,257.

Mitra, K. and Varma, S.K.(1947), Indian J.Med.Res., 35, 23.

Mickelsen, O., and Young, M.G.(1966), Federation Proc., 25, 104.

Melnick, D., Oser, B.L. and Weiss, S. (1946), Science, 103, 326.

Mitchell, H.H., Hamilton, T.S. and Beadles, J.R. (1952), J.Nutrition, 48, 461.

Mackdani, D.D., Huber, J.T. and Bergen, W.G. (1971), J.Nutrition, 101, 367.

Murray, H.C., Hellenbarger, S. and Armbruster, G.A, (1952), Agron. J. 44, 252.

Munk, L. (1966), Qual, Plant Mater. Vegetabiles, 13, 105.

Nielands, J.B., Sirny, R.J., Sohljell, I. strong, F.M. and elvehjem, C.A. (1949), J.Nutrition, 39, 187.

Nehring, K. and Schwerdtfeger, E; (1951), Arch.Tierernahrung, 1, 295.

Narasinga Rao, M., Sreevivas, H. and Morgan, C.B. (1963), J.Sci. Fd. Agri., 14, 544.

Narasinga Rao, P.S. and Patuwardhan, V.N.(1954), Indian J. med.Res., 42, 543.

Nitsan,2 (1965), Poultry scinnce 44, 1030,

Nesein, M.C. and Garlick, J.D. (1966), J.Nutrition, 88, 187.

Nebring, K. and Schwerdt figer,E. (1951), Arch.Tuernabrong, ~~Tierer~~ 1, 295.

Nitsan , Z. (1971), J.Sci.Focd.Agr., 22, 252.

Narayanaswami, D., Desai, B.L.M., Daniel, V.A., Kurian, S., Swaminathan, M.and H.A.B.Parpia (1970), Nutr.Res. Int., 2, 225.

Nirmala, D.S., Zachariah, S.and Devadas, R.D. (1968), J.Nutr.Dietet.(India), 5, 154.

Niyogi, S.P., Narayanan, N. and Desai, B.G. (1931), Indian J.med.Res., 18, 1217.

Niyogi, S.P., Narayana, N. and Desai, B.G. (1932), Indian J. Med. Res., 19, 859.

Osborne, T.B. (1894), J.Amer.chan.Soc,, 16, 663.

Osborne, T.B. (1910), Ergulan, Physio, 10, 119.

Orten, A.U. and Orten, J.M. (1946), J.Nutrition 31, 765.

Osborne, T.B. and Mendel, L.B. (1914) J. Biol chem., 17, 325.

Osborne, T.B. and Mendel, L.B. (1917) J. Biol.chem, 32, 369.

Osborne, T.B. and Mendel, L.B. (1917) J. Biol.chem., 32, 369.

Oser, B.L. (1955), Hawk's Physiological Chemistry, 14th Ed. Mc Graw-Hill Book Company, New York.

Phansalkar, S.V., Patwardhan, V.N and Ramachandran, M. (1957), Indian J. Med. Res., 45, 611

Pommerenke, Slavin, Karicher and Whipple (1935), J.Expt. Med., 61, 261.

Pigmore, J.R., Bothwell, J.W. and Williams, J.N., Jr. (1955) Proc. Soc. Exptl. Biol. Med., 88, 43.

Pecora, L.J. and Hundley, J.M. (1951), J. Nutrition, 44, 101.

Patwardhan, V.N. and Jijayaraghavan, P.K. (1954), Indian J. Med. Res., 42, 521.

Putzai, A. (1967), Nutr. Abst. Rev., 37, 1.

Powrie, W.D. (1961), J. Agri. Food Chem., 9, 67.

Rose, W.C. (1937), Science, 86, 298.

Romanoff, A.L. and Romanoff, A.J. (1949), The Avian egg, John Wiley and Sons, N.Y.

Rugamer, W.R., Poling, C.E. and Lockhart, H.B. (1950) J. Nutrition, 40, 231.

Reay, G.A., Cutting, C.L. and Stewan, J.M. (1943), J. Soc. Chem. Indi., 62, 77.

Russel, W.C., Tylor, M.V., Mehrhof, T.G. and Hirsch, A.R. (1946), J. Nutrition, 32, 312.

Richardson, L.R. (1948), J. Nutrition, 36, 451.

Rackis, J.J. (1965), Federation Proc., 24, 1488.

Rosanberg, H.R. and Culik, R. (1957), J. Nutrition, 63, 477.

Rosanberg, H.R., Kulik, R. and Eckert, R.E. (1959), J. Nutrition, 69, 217.

Russel, W.C., Taylor, M.W., Mehruof, T.G. and Hirsch, R.R. (1964), J. Nutrition, 32, 313.

Sure, B. (1948), J. Nutrition, 36, 65.

Sure, B. and Easterling, L. (1952), J. Nutrition, 48, 401.

Schoenheimer, R. (1942), "The dynamic state of body constituents"

Sauberlich, H.E., Chang, W.Y. and Salmon, W.D. (1953), J. Nutrition, 51, 241.

Saha, K.C. and Guha, B.C. (1940), Indian J. Med. Res., 27,873.

Sure, B. (1952), Arch. Biochem. Biophys., 39, 163.

Sure, B. (1953), J. Agri. Food Chem., 1, 626.

Schulz, J.A. and Thomas, B.H. (1949), Ceral Chem., 26, 639.

Sure, B. (1946), Proc. Soc. Exptl. Biol. and Med., 61, 342.

Sure, B. (1947), J. Amer. Dietet. Assoc.,23, 113.

Sure, B. (1955), J. Amer. Dietet. Assoc., 31, 1232.

Subrahmanian, N., Lekshminarayana Rao, M.V. and Srinivasan, M. (1952), Curr. Sci., 21, 339.

Sundaram, P.S., Norries, R.V. and Subrahmaniam, V. (1929), J. Indian Inst. Sci., 12A, 193.

Soifer, P.A. (1952), Biokhimiya, 17, 307.

Salmon, W.D. (1943), J. Home. Ecom., 35, 201.

Sherwood, R.W., Weldon, V. and Peterson,W.J. (1954), J. Nutrition, 52, 199.

Shyamala,G.Kennedy,B.M. and Lyman,R.L.(1961), Nature, 192, 360

Sohonie, K. and Bhandarkar, A.P. (1954), J. Sci. Industr. Res., 14C,500.

Smith, A.K., Rackis, J.J;, M.C. Kinney, L.L., Robbins, D.J. and Booth, AnN. (1964),Feed Stuffs, 36, 46.

Saxena, H.C., Jensen, L.S. and McGinnis, (1963), Poultry Science, 42, 788.

Sivaraman, E. and Maggie Menacherry, (1967), Indian Vety. J., 44, 2.

Sivaraman, E. (1968), "Biological evaluation of the Nutritive value of pulses". Thesis submitted to the Calicut University for the award of M.Sc. degree.

Harward Univ. Press Cambridge.

Stargiss and Farrar, (1935), J. Expt. Med., 62, 457.

Sugahara, T. and Sugahara, N. (1963), Jap. J. Nutrition, 21, 55.

Sure, B. (1955), J. Amer. Dietet. Assoc., 31, 1232.

Stokes, J.L., Gunness, M., Dnyer, I.M. and Casewell, M.C. (1945), J. Biol. Chem., 160, 35.

Sundrarajan, A.R. (1950), Indian J. Med. Res., 38, 29.

Sumner, E.E. (1938), J. Nutrition, 16, 129.

Swaminathan, M. (1937a), Indian J. Med. Res., 25, 399.

Swaminathan, M. (1937 b), Indian J. Med. Res., 25, 57.

Swaminathan, M. (1937 c), Indian J. Med. Res., 24, 767.

Swaminathan, M. (1937 d), Indian J. Med. Res., 25, 57.

Swaminathan, M. (1937 e), Indian J. Med.Ress, 24, 767.

Swaminathan, M. (1937), Indian J. Madras Med. Res.,24,399.

Sure,B. (1946), J. Nutrition, 36, 65.

Sumber, E.E. and Murlin, J.R. (1938), J. Nutrition, 16, 141.

Saha, K.C. and Guha, B.C. (1940), Indian J. Med. Res., 27, 873.

Saha, K.C. and Ghoss, N.C. (1941), Ann. Biochem. and Exptl. Med. 1, 159.

Sure, B. and Easterling, L. (1952), J. Nutrition, 48, 401.

Subrahmaniam, V., Narayana Rao, M., Rama Rao, G. and Swaminathan, M. (1955), Brit. J. Nutrition, 2, 350.

Sadhasivan, V. and Sreenivasan, A. (1938), J. Agri. Sci., 26, 139.

Steenbock, H. and Nelson, E.M. (1923), J. Biol. Chem., 56, 355.

Smith, J.R. Jr., Earle, F.R. and Wolff, I.A. (1959), J. Agr. Food Chem., 7, 133.

Seedl, D., Jaffe, M. and Jaffe, W.G. (1969), J. Agri. Food Chem., 17, 1318.

Swaminathan, M. (1967), "Newer Methods of Nutritional Biochemistry". Ed. A. A. Albanese, Academic Press, New York.

Subba Rao, G.N. and Subrahmaniam, V. (1950), Proc. Soc. Biol. Chem. (India), 2, 22.

Sohonie, K. and Bhandarkar, A.P., (1955), J. Sci. Ind. Res. (India), 14C, 100.

Sohonie, K. and Ambe, K.S. (1955), Nature, 175, 508.

Sohonie, K. and Ambe, K.S. (1959), Nature, 75, 508.

Swaminathan, M.S. (1971), "New Vistas in Pulse Production" Ed. S. Ramanujam and A.K. Sharma, I.A.R.I., New Delhi.

Tauber, H., Hershaw, B.B. and Wright, R.D. (1949), J. Biol. Chem., 179, 1155.

Tandon, O.B., Bressani, R., Crimshaw, N.S. and Le Bean, F. (1957), J. Agr. Food Chem., 57 5, 137.

Tara, M.R., Rawal, T.N. and Rama Rao, M.V. (1972), J. Nutrition Dietet., 9, 208

Tasker, P.K., Narayana Rao, M., Swaminathan, M., Sankaran, A.N., Jayaraj, A.P. and Subrahmaniam, V. (1961), J. Agr. Food Chem., 2, 413.

Vijayaraghavan, P.K. and Srinivasan, P.R. (1953), J. Nutrition, 51, 261.

Vogel, R. and Hartwing, G. (1966), Cited by Vogal et al., 1966, p. 27.

Vogel, R., Transtchold, I. and Warle, E. (1966), "Taturliche Proteinasen Inhibitoren". Thieme, Stuttgart, Germany.

Venkat Rao, S., Leela, R., Swaminathan, M. and Parpia, H.A.B. (1964), J. Nutr. Dietet, 1, 304.

Venkat Rao, S., Soma Kurian, Narayanaswami, D., Rajalekshmy, D. and Swaminathan, M. (1971), Nutr. Rep. Int., 3, 189.

Vijayalekshmy, D., Soma Kurian, Narayanaswami, D., Venkat Rao, S. and Swaminathan, M. (1972), The Indian J. Nutr. Dietet., 9, 129.

Van Etten, C.H., Kwolek, W.F., Peters, J.E. and Barclay, A.S. (1967), J. Agr. Food Chem., 15, 1077.

Wong, (1928), J. Biol. Chem., 77, 409.

Whipple, G.H. (1940), Ann. Surg., 112, 481.

Whipple, G.H. and Madden, S.L. (1940), Physiol. Rev., 20, 194.

Waino, W.M., Eichel, B., Eichel, H.J., Pearson, F.L., Ester, F.L. and Allison, J.B. (1953), J. Nutrition, 49, 465.

William, J.N. Jr., Elvehjem, C.A. (1950), J. biol. Chem., 183, 539.

Williams, J.N. Jr. (1963), Arch. Biochem. Biophys., 101, 512.

Woddle, (1958), Processed Plant Protein Food Stuffs. Ed. A. M. Altschul, Academic Press, I.N.C. Publishers, New York.

Williams, M.B. (1944), J. Biol. Chem., 156, 47.

Williams, R.R. (1952), J. Amer. Dietet. Assoc,, 28, 269.

Woodworth, C.M., Leug, E.R. and Jugenheimer, R.W. (1952), Agrohom. J., 44, 60.

Westman, B.D., Roach, F. and Stone, M. (1952), J. Nutrition, 47, 147.

Westerman, B.D., Oliver, B. and May, E. (1954), J. Nutrition, 54, 255.

Westfall, R.J. and Hauge, S.M. (1948), J.Nutrition, 35, 352.

Waterman, H.C. and Jones, D.V. (1921), J. Biol. Chem., 47, 285.

West, Q.M. (1969), "Protein enriched cereal food for world needs". Ed. Milner Amer. Ass. of cereal chemists, Minnesotta.

Woods, E., Beeson, W.M. and Bolin, D.W. (1943), J. Nutrition, 26, 327.

Yesoda, K.M. (1942), Curr. Sci., 11, 360.

Yesoda, K.M. (1945), Curr. Sci., 14, 77.

Yesoda, K.M. and Damodaran, M. (1947), Biochem. J., 41, 382.

Reprint from THE INDIAN VETERINARY JOURNAL
Vol. 44, No. 2, February 1967.

STUDIES ON THE NUTRITIVE VALUES OF COW PEA (*Vigna catjang*) AND TUR DHAL (*Cajanus cajan*)

BY

E. SIVARAMAN and MAGGIE MENACHERY

Nutrition Laboratory,
Kerala Veterinary College and Research Institute,
Mannuthy, Trichur

Pulses constitute the chief source of dietary protein for many fragments of the world's population, especially in regions where animal protein is in short supply or where most people do not consume fish, egg or meat in any form. Besides being an excellent source of vegetable protein to the human population, leguminous crops also provide good fodder for livestock. From nutritional point of view, pulses not only supplement cereals (Bressani, *et al* 1962) but on account of the differences in the amino acid compositions of the constituent proteins they also supplement each other (Phansalkar and Patwardhan, 1964). Although great deal of work on the nutritive values and supplementary effects of wide varieties of pulses has been carried out (Venkita Rao *et al* 1964), comparatively very little work has been done in this regard with cow pea (*Vigna catjang*) and tur dhal (*Cajanus cajan*)- two important sources of nitrogenous foods for man and livestock. It was therefore considered essential to know more about the nutritive values of these two pulses, in order to judge how far these could be reckoned as nutritionally adequate as nitrogenous foods when fed as the sole source of dietary nitrogen. Accordingly, an investigation was carried out to assess the nutritive values of cow pea and tur dhal, choosing albino rats as experimental subjects and weight gain and red blood cell (R.B.C), haemaglobin (Hb) and plamsa protein concentrations of the animals as the creteria. Results of this study are reported in the present paper.

Materials and Methods

Diets :- Three isoproteimic diets were used in the investigation, one containing 70 parts of cow pea flour (Diet A), another containing 70 parts of tur dhal flour (Diet B) and the third containing 18 parts of casein (diet C). Diet C served as control. The composition of the diets is described in Table 1. Seventy parts of cow pea flour and 70 parts of tur dhal flour contained respectively 15·0 and 14·1 parts of protein (N x 6·25). The protein level was made up to 18 parts in diets A and B on nitrogen basis by the addition of the required amounts of protein isolated from cow pea and tur dhal respectively.

TABLE 1

Percentage composition of the diets with average food intakes.

Diet	Cow pea flour	Tur dhal flour	Amylum	Protein supplement	Hydrogenated vegetable oil	Sucrose	Salt* mixture	Average daily food intake in gm.
A	70	—	—	3 (Cow pea protein)	5	17	5	6·1
B	—	70	—	3·9 (Tur dhal protein)	5	16	5	5·2
C	—	—	60	18 (Casein)	5	12	5	5·5

* Steen bock — Nelson Salt Mixture (Steen bock and Nelson, 1923; Pearson, Elvehjem and Heart, 1937) No. 40 plus 0·03 Percent $CuSo_4\ 5H_20$

Animals: Forty two young albino rats of the College stock colony were distributed into groups of 14 each, as evenly as possible in regard to age, weight and sex. The animals were housed in individual cages with raised screen bottoms. The three groups of animals were maintained on the respective diets (Diets A, B and C) for a period of 28 days. In addition to the diets, all animals were given "Adexolin" (Glaxo) corresponding to 300 i.u. of Vitamin A and 50 i.u. of Vitamin D per rat per day, 3. mg. of Vitamin E (α – tocopherol) per rat once a week and the following daily supplements of water-soluble vitamins of the B complex: thiamine hydrochloride 50 μg., riboflavin 50 μg., pyridoxin hydrochloride 100 μg., nicotinic acid 100 μg., calcium pantothenate 100 μg. and choline chorlde 5 mg. The animals were fed *ad lib* and were weighed once a week. Daily food intake records were maintained.

Materials: Cow pea and tur dhal required for the preparation of the experimental diets A and B were purchased locally, dried at 80°C. in a hot air oven and powdered first with the aid of a Wiley mill and subsequently with pestle and mortar. Proteins from cow pea and tur dhal for incorporation into diets A and B respectively were prepared by extraction of the respective flour with 3·5% (W/V) NaCl. solution, precipitation from the solution at full saturation with $(NH_4)_2\ SO_4$, redissolving the precipitates in water followed by filtration and reprecipitation by heat coagulation at 100°C. The heat coagulated proteins were washed free from $(NH_4)_2\ SO_4$ and dried with acetone. Casein required for the study was prepared from skim milk powder according to the method described by Cohn and Hendry (1930).

Methods :- The chemical composition of cow pea and tur dhal was worked out following the standard methods described in A.O. A.C. (Association of Official Agricultural Chemists, 1955). For the determination of r. b. c., haemoglobin and plasma protein concentrations, the procedure described by Chandran and Ambegoaker (1959) was adopted. Blood samples for the determination of red cells and haemoglobin concentrations were obtained by snipping the tail of the rat. Plasma protein was estimated on the pooled samples of plasma obtained after centrifugation of the blood withdrawn by heart puncture from the animals maintained on the respective diets (Diets A, B and C). Sodium citrate was used as the anticoagulant. Plasma protein determinations (Total plasma nitrogen x 6·25) were made only at the beginning and at the end of the experiment. Non-protein nitrogen was not estimated.

Results and Discussion

The chemical composition of the two pulses is set out in Table 2. The data indicate that essentially, cow pea and tur dhal possess more or less an identical chemical composition. The average values for weight gain and r.b.c., haemoglobin and plasma protein concentrations of the three groups of animals are presented in Table 3. The results were statistically analysed according to the method described by Snedecor (1956).

TABLE 2

Percentage composition of cow pea and tur dhall

Constituents		Cow pea	Tur dhal
Moisture	...	6·2	6·9
Crude protein	...	21·4	20·2
Ether extractives	...	1·3	1·9
Crude fibre	...	4·6	1·2
Nitrogen free extract	...	62·0	66·9
Ash	...	4·5	2·9
Cao	..	0·35	0·99
P_2O_5	...	0·52	0·75

Since purified proteins of cow pea and tur dhal were not used in place of the respective flours in the preparation of the diets A and B, the diets A and B can hardly be designated as truly synthetic. Nevertheless,

in as much as these diets are isoproteimic and essentially similar in almost all respects, it would appear that the results are attributable to the quality of proteins in the respective diets.

TABLE 3

Average values with standard error for Body weight (gm.) and R. B. C. (mill/mm³), Hb. (gm./100 ml.) and Plasma protein concentrations (gm./100 ml.) of rats maintained on different diets.

Diet	No. of animals		Days				
			0	7	14	21	28
A	14	Weight	61±2·19	68±3·01	70±3·58	77±3·47	80±3·72
		R. B. C.	7·66±0·32	8·01±0·15	8·59±0·22	8·63±0·25	8·86±0·28
		Hb	11·9±0·15	12·0±0·16	12·1±0·19	13·8±0·23	14·4±0·43
		Plasma protein	5·71	—	—	—	6·95
B	14	Weight	62±2·05	68±2·58	58±2·66	61±3·40	65±3·01
		R. B. C.	7·58±0·27	8·18±0·24	8·36±0·13	8·47±0·28	8·61±0·22
		Hb	12·1±0·19	12·3±0·21	12·5±0·34	13·4±0·19	14·0±0·31
		Plasma protein	5·94	—	—	—	6·12
C	14	Weight	62±2·20	67±3·05	73±3·26	78±3·40	86±4·07
		R. B. C.	6·95±0·16	7·86±0·18	8·47±0·21	8·35±0·13	8·2±0·22
		Hb	12·0±0·16	12·4±0·18	12·5±0·14	13·9±0·22	14·4±0·32
		Plasma protein	5·95	—	—	—	6·55

Statistical significance of gain in weight between diets

't' values

C Vs A	C Vs B	A Vs B
0·91	3·95 *	3·14 *

* Significant at 1% level.

It will be seen from Table 3 that the animals fed the control diet C and those maintained on the isoproteimic diet A show a growth response of 23·0 and 19·0 gm. respectively during the experimental period of 28 days, whereas the weight gain of animals receiving the isoproteimic diet B is as low as 3·0 gm. during the period. Statistical analysis of the results clearly indicates that diets A and C possess better growth promoting values than Diet B, the difference between the final weights attained at the end of the experimental period (28 days) by the animals maintained on diets A and C on one hand and the weight attained by those receiving diet B on the other being highly significant. The analysis further reveals that diet A is nearly as effective as the control diet C in inducing growth in the rats, as the difference between

the final weights attained by these two groups is not statistically significant. It is thus seen that cow pea possesses a good quality protein source and that the nutritive value of cow pea protein for promoting growth is superior to that of tur dhal protein. This inference is found to be in accord with the assessment of the probable nutritive values of these two pulse proteins from a knowledge of their respective amino acid compositions (Patwardhan and Ramachandran, 1960).

It will be evident from Table 3 that all the three diets support the concentration of r.b.c., hemoglobin and plasma protien in the rats, as animals in all groups maintained normal levels for these constituents throughout the course of the experiment (28 days). It will be seen further that diet B which does not support somatic growth in the rat promotes the formation of blood proteins in the animals. This interesting observation stressed the need to revaluate the nutritive values of the three diets in terms of the specific physiological function of red cell and haemoglobin formation. Since normal animals are of little use for purposes of such studies on account of the fact that these animals seldom show any marked response on the blood picture either to protein supplementation or to protein deficiency, these experiments had to be carried out on adult rats rendered anaemic by phenylhydrazine as described by Yeshoda and Damodran (1947).

Rate of recovery of rats maintained on diets A, B and C from Phenylhydrazine anaemia

The results of this investigation as also the statistical analysis of the data presented in Tables 4 and 5 respectively clearly indicate that while there is no significant difference between the three groups in the rate of regeneration of red cell from the 4th to 16th day of the experiment, there is a significantly higher rate of regeneration of haemoglobin in the case of animals receiving the control diet C during the period, the diets A and B showing no significant difference between them in their ability to promote haemoglobin synthesis. In regard to body weight, it is found that animals receiving diet A show a slight gain in weight comparable with that of animals maintained on the control diet C containing casein, while in marked contrast, those fed diet B show a significant reduction in weight during the experimental period. It is quite probable that from the breakdown of body tissues, additional amounts of such limiting amino acids in tur dhal protein as tryptophan, methionine and histidine (Patwardhan and Ramachandran, (*loc. cit*) might have become available for haemoglobin synthesis in the case of animals receiving diet B, as otherwise it is quite unlikely that these animals could have shown haemoglobin levels comparable with those of animals maintained on diet A.

TABLE 4

Recovery of rats maintained on diets A. B and C from Phenylhydrazine anaemia (Mean values of body weight in gm., R. B. C. in mill/mm³ and Hb in gm /100 ml with standard error).

Diet	No. of animals		Days on experiment.							
			0	4	8	12	16	20	24	28
A	8	Weight	152±8·5	—	159±9·1	—	—	159±8·2	—	158±7·9
		R. B. C.	6·95±0·2	4·81±0·09	5·61±0·2	6·51±0·11	6·65±0·04	6·87±0·05	6·94±0·05	—
		Hb	14·9±0·06	10·5±0·47	12·4±0·28	12·8±0·17	13·5±0·40	14·3±0·28	14·6±0·20	—
B	8	Weight	152±9·3	—	156±8·6	—	—	135±9·5	—	133±11·1
		R. B. C.	6·7±0·09	4·86±0·07	5·42±0·02	6·42±0·07	6·52±0·05	6·78±0·06	6·53±0·08	—
		Hb	15·5±0·1	10·1±0·28	12·2±0·26	13·5±0·14	13·6±0·30	14·0±0·31	14·4±0·14	—
C	8	Weight	154±8·5	—	159±8·1	—	—	159±7·7	—	160±7·4
		R. B. C.	6·64±0·15	4·80±0·04	5·38±0·08	6·32±0·09	6·72±0·12	6·91±0·07	6·98±0·2	—
		Hb	15·2±0·14	9·70±0·24	11·3±0·48	13·1±0·25	14·3±0·25	14·5±0·19	15·0±0·3	—

TABLE 5

Statistical significance of the data presented in Table 4 ('t' values)

Groups compared	Body weight gain (between 0–28th day)	Rate of regeneration of R.B.C. (between 4th – 16th day)	Rate of regeneration of Hb (between 4th – 16th day)
C vs. A	0·0	0·45	2·76**
C vs. B	6·26*	1·70	2·19**
A vs. B	4·94*	1·27	0·78

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

An assessment of the over-all results of this investigation points to show that the protein of cow pea possesses a better nutritive value than that of tur dhal. However, its superiority in this regard over tur dhal protein can be explained in qualitative and quantitative terms of amino acid requirements of the rat, only after further experimentation with purified diets with and without supplements of the varying limiting amino acids in the respective proteins.

Summary

The nutritive values of cow pea (*Vigna catjang*) and tur dhal (*Cajanus cajan*) were investigated using albino rats as the experimental subjects and choosing weight gain and red cell, haemoglobin and plasma protein concentrations of the animals as the criteria. It was found that cow pea flour incorporated in a diet at a 18% protein level on nitrogen basis promotes, on feeding for a period of 28 days, a significantly higher growth response in the rats than tur dhal supplied through an isoproteimic diet. The growth rate obtained with cow pea flour is found to be essentially the same as that observed with a control diet containing 18% casein as the sole source of nitrogen. While no significant difference is noticed between the diets in their ability to support the formation of red cell, haemoglobin and plasma protein in the normal growing rats, assessment of the haemopoietic response in adult animals by the phenylhydrozine anaemia technique showed that for promoting haemoglobin formation, the two pulse protein diets are less efficient than the control diet containing casein. The significance of these observations is discussed briefly.

Acknowledgment

Grateful acknowledgment is made to Dr. C. T. Peter, Principal, Kerala Veterinary College and Research Institute, for permission to

publish these results and to Dr. K. Chandra Menon, Professor of Animal Husbandry (Nutrition) for supervision and guidance. Thanks are also due to Sri K. Easwarankutty Warrier, Statistician, Kerala Veterinary College and Research Institute, for statistical analysis of the results and to Miss. Mariamma Kurian and Mrs. Elezebeth Benny, Research Assistants for technical help.

REFERENCES

Bressani, R. Valiente, A. T. and Tajeda, D. E. (1962) ... *J. Fd. Sci.*, 27 : 394.

Chandran, K. and Ambegaokar, S.D. (1959) ... *Indian J. med. Res.* 47 : 552.

Cohn, E. J. and Hendry, J. L. (1930) ... Organic Synthesis collective, vol. 2,, edited by A. H. Blatt (John Wiley and Sons Inc., New York) 1963, 120.

Official Methods of Analysis (1930) ... Association of Official Agricultural Chemists, Washington.

Patwardhan, V. N. and Ramachandran, M. (1960) ... *Curr. Sci.*, 25 : 401.

Phansalkar, S. V. and Patwardhan, V. N. (1964) ... *Indian J. med, Res.*, 44 : 1.

Snedecor, G. W. (1956) ... Statistical Methods, 5th ed.. Iowa State College Press, Iowa.

Venkita Rao, S., Leela, R., Swaminathan, M. and Parpia, H. A. B. (1964) ... *J. Nutri. Dietet.*. 1 : 804.

Yeshoda, K. M. and Damodaran, M. (1947) ... *Biochem. J.*, 47 : 382.

APPENDIX

APPENDIX

Summarised results of the work carried out by the author for the award of the M.Sc. degree:

Experiments were carried out with young albino rats as experimental subjects to study (1) the comparative effects of feeding cowpea and tur dhal at 18% protein level (on Nitrogen basis) on growth and red cell, haemoglobin and plasma protein concentrations and (2) assess the relative ability of the isolated proteins of cowpea and tur dhal when fed at 10% protein level, with and without supplementation of either methionine or tryptophane or both in terms of such physiological responses as growth, protein efficiency ratio (P.E.R.), nitrogen retention, biological value, red cell, haemoglobin and plasma protein concentrations, liver protein and liver fat contents. The effects of the diets on feeding on the haematopoeitic responses of animals rendered anaemic by intraperitonial injections of phenyl-hydrazine were also assessed during the course of the present study.

Table I

Percentage composition of experimental diets.

Diets	Cowpea flour	Tur dhal flour	Amylum	Protein supplement.	Protein source	Hydrogenated vegetable oil	Sucrose	Salt* Mixture
Experiment I								
A	10.0	--	--	3.0 cowpea protein	--	5.0	17.0	5.0
B	--	70.0	--	3.9 tur dhal protein	--	5.0	16.1	5.0
C	--	--	60.0	--	18.0 casein	5.0	12.0	5.0
Experiment II								
D	--	--	65.0	--	10.0 cowpea protein	5.0	15.0	5.0
E	--	--	65.0	--	10.0 tur dhal protein	5.0	15.0	5.0
F	--	--	65.01	--	10.0 casein	5.0	15.0	5.0
G*	--	--	65.0	--	10.0 cowpea protein	5.0	15.0	5.0
H*	--	--	65.0	--	10.0 tur dhal protein	5.0	15.0	5.0

*Diets G and H were supplemented with methionine and tryptophane in such amounts as were essential to meet minimum requirements. *Steenbock and Nelson salt Mixture No.40+0.03% $CuSO4, 5H_2O$.

Table II

Recovery of rats maintained on diets containing cowpea and tur dhal at 18% protein level, from phenylhydrazine anaemia

(Mean values of body weight in g, R.B.C. in mill./mm^3 and Hb. in g/100ml)

Diets	No. of animals.		No. of days on experiment.							
			0	4	8	12	16	20	24	28
A	8	weight	152.0±8.5	-	159.0±9.1	-	-	159.0±8.2	-	158.0±7.9
		R.B.C.	6.95±0.2	4.81±0.09	5.61±0.2	6.51±0.11	6.65±0.04	6.87±0.05	6.94±0.05	-
		Hb.	14.9±0.06	10.5±0.47	12.4±0.28	12.8±0.17	13.5±0.40	14.3±0.23	14.6±0.20	-
B	8	weight	152.0±9.3	-	156.0±8.6	-	-	135.0±9.5	-	133.0±11.1
		R.B.C.	6.7±0.09	4.86±0.07	5.42±0.02	6.42±0.07	6.52±0.05	6.78±0.06	6.53±0.08	-
		Hb.	15.5±0.1	10.1±0.23	12.2±0.26	13.5±0.14	13.6±0.30	14.0±0.31	14.4±0.14	-
C	8	weight	154.0±8.5	-	158.0±8.1	-	-	159.0±7.7	-	160.0±7.4
		R.B.C.	6.64±0.15	4.80±0.04	5.38±0.08	6.32±0.09	6.72±0.12	6.91±0.07	6.98±0.2	-
		Hb.	15.2±0.14	9.7±0.24	11.3±0.48	13.1±0.25	14.3±0.25	14.5±0.19	15.0±0.3	-

Statistical significance:

	Rate of regeneration of R.B.C.(4-16th day)	Rate of regeneration of Hb. (4-16th day)
C Vs A	0.45	2.76**
C Vs B	1.70	2.19*
C Vs B	1.27	0.78

**Significant at 1 % level

*Significant at 5 % level

Table III

Effects of diets containing cowpea and tur dhal at 18% protein level on body weight (g.) and R.B.C. (mill.0mm^3), haemoglobin (g/100 ml.) and plasma protein concentration (g./100 ml)

Diets	No. of animals		Days				
			0	7	7	14	21	28
A	14	Weight(g.)	61.0±2.19	68.0±3.01	70.0±3.47	77.0±3.47	80.0±3.72
		R.B.C. (mill./mm^3)	7.66±0.32	8.10±0.15	8.59±0.22	8.63±0.25	8.86±0.28
		Haemoglobin (g./100 ml)	11.9±0.15	12.0±0.16	12.1±0.19	13.8±0.23	14.4±0.43
--		Plasma protein (")	5.71	--	--	--	5.95
B	14	Weight (g.)	62.0±2.05	58.0±2.58	58.0±2.56	61.0±3.40	65.0±3.01
		R.B.C. (mill./mm^3)	7.58±0.27	8.18±0.24	8.36±0.13	8.47±0.28	8.61±0.22
		Haemoglobin (g./100 ml)	12.1±0.19	12.3±0.21	12.5±0.34	13.4±0.19	14.0±0.31
		Plasma Protein (")	5.94	--	--	--	6.12
C	14	Weight (g.)	62.0±2.20	67.0±3.05	73.0±3.26	78.0±3.40	85.0±4.07
		R.B.C. (mill./mm^3)	6.95±0.16	7.86±0.18	8.47±0.21	8.35±0.13	8.2 ±0.22
		Haemoglobin (g./100ml)	12.0±0.16	12.4±0.18	12.5±0.14	13.9±0.22	14.4±0.32
		Plasma Protein (")	5.95±	--	--	--	6.55

Average values with standard error.

Statistical significance of gain in weight between diets

't' values: C Vs A = 0.91, C Vs B = 3.95**, A Vs B = 3.14**

** Significant at 1% level.

Table IV

Effect of feeding cowpea protein and tur dhal protein diets with and without supplementation of the limiting amino acids (Diets D, E, F, G and H) on body weight gain

Diets	No.of animals	Weeks							
		0	1	2	3	4	5*	6**	7***
D	6	38.3±0.63	34.3±0.56	35.5±0.67	38.0±0.89	37.7±1.17	52.5±1.47	59.3±1.85	77.7±2.78
E	6	37.5±2.74	36.7±2.40	34.3±2.0	33.5±1.90	34.5±2.04	40.7±2.48	47.8±8.16	66.0±2.45
F	6	37.3±2.01	43.0±1.67	49.3±1.85	56.6±0.84	70.0±1.78	75.5±1.45	81.5±1.99	87.3±2.21
G	6	37.5±3.0	52.0±4.90	59.0±4.70	66.8±6.10	91.0±6.30	85.8±5.71	99.5±5.10	100.3±5.03
H	6	37.5±2.74	47.2±3.53	53.2±3.37	57.8±3.96	76.0±4.55	73.6±4.04	78.3±3.93	77.3±4.09

* Methionine added to diet D; Tryptophane added to diet E
Methionine withheld from diet G ; Tryptophane withheld from diet H.

** Tryptophane added to diet D; Methionine added to diet E
Tryptophane withheld from diet G; Methionine withheld from diet H.

*** Methionine and tryptophane added to diets D and E
Methionine and tryptophane withheld from diets G and H

Table V

Effect of feeding - Cowpea protein and tur dhal Protein at 10% level with and without supplementation of limiting essential amino acids

Average values with st. error (6 animals/group)

(Diets D, E, F, G and H) on growth and P.E.R.

Diets	No. of animals	Body weight		Weight gain	Food intake	Protein intake	Protein efficiency ratio
		Initial	Final				
D	6	38.3±0.63	37.3±1.17	-0.7±1.18	96.8±3.88	9.7±0.38	-0.08±0.22
E	6	37.5±2.74	34.5±2.04	-3.01±1.37	82.7±4.63	8.3±0.48	-0.37±0.51
F	6	37.3±2.01	70.0±1.78	32.6 ±1.33	126.3±8.38	12.6±0.84	2.65±0.22
G	6	37.5±3.0	91.0±6.3	53.5±4.39	154.3±8.74	15.4±0.79	3.45±0.11
H	6	37.5±2.74	76.0±4.55	38.5±3.95	126.0±4.89	12.6±0.49	2.19±0.19

	D. Values	
	5% level	1% level
*Weight gain in (g.)	11.73	14.52
*Protein efficiency ratio	0.79	0.98

*Difference between any two averages, if greater than D. values, is significant.

Table VI

Effect of feeding cowpea protein and tur dhal protein diets with and without supplementation of the limiting essential amino acids (Diets D, E, F, G and H) on Red cell concentration

(R.B.C. in millions/mm^3-Average values)

Diets	No. of animals	Food intake (g.)	Weeks							
			0	1	2	3	4	5*	6@	7$
D	6	3.5	7.03	7.16	7.59	7.47	7.55	7.62	7.91	8.18
E	6	2.9	6.88	7.08	7.07	7.15	7.74	7.76	7.74	7.84
F	6	4.5	6.95	7.26	7.28	7.57	7.82	7.86	7.89	7.95
G	6	5.5	6.99	7.29	7.36	7.45	7.81	7.53	7.85	7.86
H	6	4.5	7.04	7.15	7.35	7.38	7.55	7.53	7.71	7.49

* Methionine added to diet D; Tryptophane added to diet E
Methionine with held from diet G ; Truptophane with held from diet H.

@ Tryptophane added to diet D ; Methionine added to diet E
Tryptophane with held from diet G ; Methionine with held from diet H.

$ Methionine and tryptophane added to diets D and E
Methionine and tryptophane with held from diets G and H.

Table VII

Effect of the diets (Diets D, E, F, G and H) on Plasma Protein concentration*
Values in g./100 ml.

Diets	Body weight of animals (g.)	Plasma protein	
		Initial	Final
D	77.7	5.8	5.3
E	66.0	5.5	4.9
F	87.3	6.0	6.4
G	100.3	6.2	6.2
H	77.3	6.0	5.7

* Average of six animals

Table VIII

Effect of feeding cowpea protein and turdhal protein diets with and without supplementation of the limiting essential amino acids (Diets D,E,F,G and H) on haemoglobin concentration

(Haemoglobin in g./100 ml.--Average values)

Diets	No. of animals	Food intake (g.)	Weeks							
			0	1	2	3	4	5*	6@	7£
D	6	3.5	14.5	14.3	14.3	14.1	14.1	14.2	14.1	14.8
E	6	2.9	14.7	13.7	13.0	13.6	14.6	14.6	14.0	14.5
F	6	4.5	14.1	14.4	14.7	15.3	15.6	15.6	15.7	15.8
G	6	5.5	14.5	14.7	15.8	15.8	15.9	15.0	15.3	14.2
H	6	4.5	14.4	14.7	15.3	15.4	15.6	14.5	13.7	13.1

* Methionine added to diet D ; Tryptophane added to diet E
Methionine withheld from diet G ; Tryptophane withheld from diet H

@ Tryptophane added to diet D ; Methionine added to diet E
Tryptophane withheld from diet G ; Methionine withheld from diet H

£ Methionine and tryptophane added to diet D and E
Methionine and tryptophane withheld from diets G and H.

Table IX

Effect of diets (Diets D, E, F, G and H) on nitrogen balance in rats and biological values (Average Values)£

	Diet					D Values *	
	D	E	F	G	H	5% level	1% level
Weight in (g.)	37.7± 0.17	34.5± 2.04	70.0± 1.78	91.0± 6.30	76.0± 4.55	-	
Body surface area cm^2	110.6± 2.08	104.0± 4.15	160.4± 2.45	187.2± 7.83	168.1± 5.98		
Nitrogen balance mg./day	24.1± 3.57	20.4± 5.08	83.8± 9.17	91.1± 4.91	58.9± 5.66	23.82	29.48
Nitrogen balance mg./100 cm^2 body surface	21.6± 2.07	18.9± 4.08	47.8± 5.82	49.0± 3.37	35.1± 3.47	16.88	20.88
Percent retention	44.0± 3.68	33.0± 4.87	79.9± 2.45	75.8± 2.84	65.1± 3.01	14.47	17.93
Biological value	40.16± 4.17	35.69± 4.74	83.27± 2.19	81.42± 2.01	77.32± 3.58	14.60	18.07

£ Average values (six animals per group) with standard error.

* Differences between any two averages, if greater than D values, is signfficant.

Table X

Effect of diets D, E, F, G and H on liver fat and liver protein contents of animals

(Average* values with standard error)

	Diet					D Values**	
	D	E	F	G	H	5% level	1% level
Body Weight in (g.)	77.7± 2.78	66.0± 2.45	87.3± 2.01	199.3± 5.03	77.3± 4.09		
Fresh weight of liver	3.68± 0.16	4.21± 0.29	4.79± 0.28	5.81± 0.39	5.54± 0.50		
Liver protein in % fresh basis	11.74± 1.10	7.66± 0.27	13.72± 0.54	12.57± 0.32	10.81± 0.52	3.25	4.02
Liver fat in fresh basis	6.46± 1.52	4.94± 0.26	3.54± 0.32	2.57± 0.19	2.69± 0.18	3.57	4.42

* Average values (6 animals per group) with standard error.

** Difference if between any two average, if greater than D values is significant.

Table XI

Recovery of rats maintained on diets A, B, and C from Phenylhydrazine anaemia (Mean values of body weight in gm., R.B.C. in mill/mm^3 and Hb in gm/100 ml with standard error).

Diet	No. of animals		Days on experiment. 0	4	8	12	16	20	24	28
A	8	weight	152±8.5	-	159±9.1	-	-	159±8.2	-	158±7.9
		R.B.C	6.95±0.2	4.81±0.09	5.61±0.2	6.51±0.11	6.65±0.04	6.87±0.05	6.94±0.05	-
		Hb.	14.9±0.06	10.5±0.47	12.4±0.28	12.8±0.17	13.5±0.40	14.3±0.23	14.6±0.20	-
B	8	weight	152±9.3	-	156±8.6	-	-	135±9.5	-	133±11.1
		R.B.C.	6.7±0.09	4.86±0.07	5.42±0.02	6.42±0.07	6.52±0.05	6.78±0.06	6.53±0.08	-
		Hb.	15.5±0.1	10.1±0.23	12.2±0.26	13.5±0.14	18.6±0.30	14.0±0.31	14.4±0.14	-
C	8	weight	154±8.5	-	158±8.1	-	-	159±7.7	-	160±7.4
		R.B.C.	6.64±0.15	4.80±0.04	5.38±0.08	6.32±0.09	6.72±0.12	6.91±0.07	6.98±0.2	-
		Hb.	15.2±0.14	9.70±0.24	11.3±0.48	18.1±0.25	14.3±0.25	14.5±0.19	15.0±0.3	-

Table XII

Effect of the five diets (Diets D, E, F, G and H) on the body weight and rate of regeneration of red cell and haemoglobin - summarised Table.(Body weight in g., R.B.C. in mill./mm^3 and haemoglobin in g./100 ml. (average values with Standard error).

Diets	No. of animals	Food intake(g)	Days after injection						
			0	4	8	12	17	20	25
D									
Body wt.	6	5.2± 0.32	119±10.6	116±10.4	114±9.1	111±6.9	113±7.7	115±6.7	115±6.3
Red cell			7.45±0.32	3.71±0.10	4.79±0.10	5.89±0.82	6.84±0.17	7.02±0.22	7.48±0.13
Haemoglobin			14.6±0.22	9.8±0.24	12.5±0.26	13.7±0.29	14.7±0.28	14.2±0.29	14.2±0.14
E									
Body wt.	6	5.0± 0.24	117±14.0	114±12.6	114±12.2	111±11.5	114±12.5	118±12.0	117±11.4
Red cell			7.65±0.31	3.37±0.25	4.59±0.11	5.89±0.09	6.84±0.21	6.82±0.19	7.29±0.11
Haemoglobin			14.7±0.45	9.1±0.57	11.7±0.30	13.1±0.19	14.7±0.35	14.2±0.24	13.6±0.27
F									
Body wt.	6	6.2± 0.40	118±17.4	119±17.1	125±20.1	130±18.7	132±19.7	134±18.6	139±19.2
Red cell			7.80±0.23	3.58±0.22	4.87±0.27	6.61±0.22	7.34±0.53	7.70±0.43	7.84±0.36
Haemoglobin			13.8±0.21	8.1±0.57	12.3±0.26	13.9±0.29	13.5±0.41	13.1±0.28	13.8±0.38
G									
Body wt.	6	5.8± 0.35	116±15.3	115±14.8	115±13.5	117±12.9	122±13.0	128±12.3	130±12.2
Red cell			6.80±0.41	3.83±0.38	4.62±0.53	5.96±0.45	6.60±0.43	6.99±0.52	7.59±0.49
Haemoglobin			13.5±0.46	9.6±0.44	11.8±0.68	13.9±0.44	14.1±0.61	13.9±0.41	14.3±0.59
H									
Body wt.	6	6.5± 0.42	114±4.5	119±12.9	119±12.0	124±11.9	125±10.9	130±10.0	133±10.4
Red cell			7.51±0.23	3.66±0.19	4.81±0.21	6.20±0.26	7.15±0.35	7.24±0.13	7.64±0.21
			14.2±0.54	9.9±0.30	12.9±0.44	14.1±0.43	14.1±0.41	13.4±0.37	14.5±0.37

Plate 1. LIVER. Note the hepatic cells showing vacuolar degeneration of cytoplasm.
Haematoxylin and Eosin x 200.

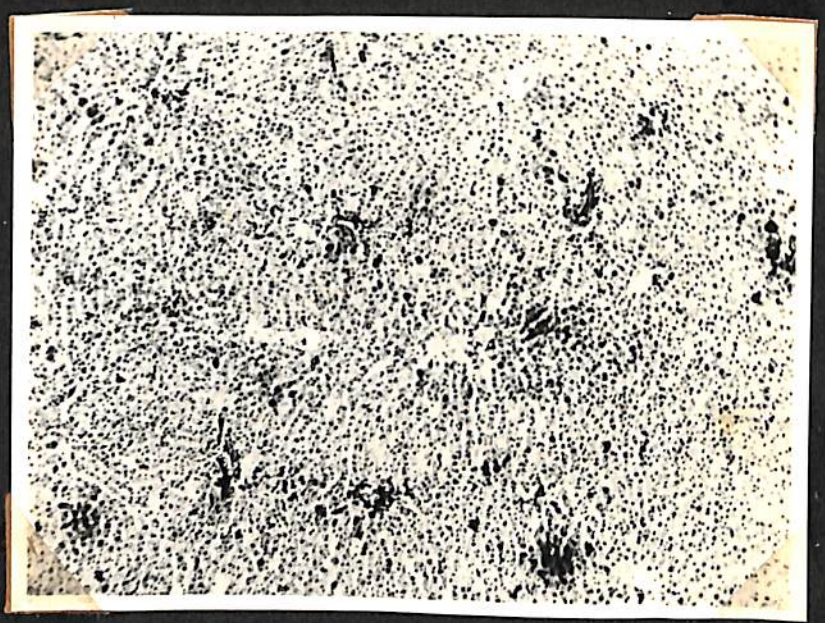


Plate 2. LIVER. Showing numerous scattered hepato megalocyte
Haematoxylin & Eosin x 100.

Plate 2 a.

LIVER. Note the numerous hepatomegalocytes with few cells in stages of mitosis. Haematoxylin and Eosin x 250.

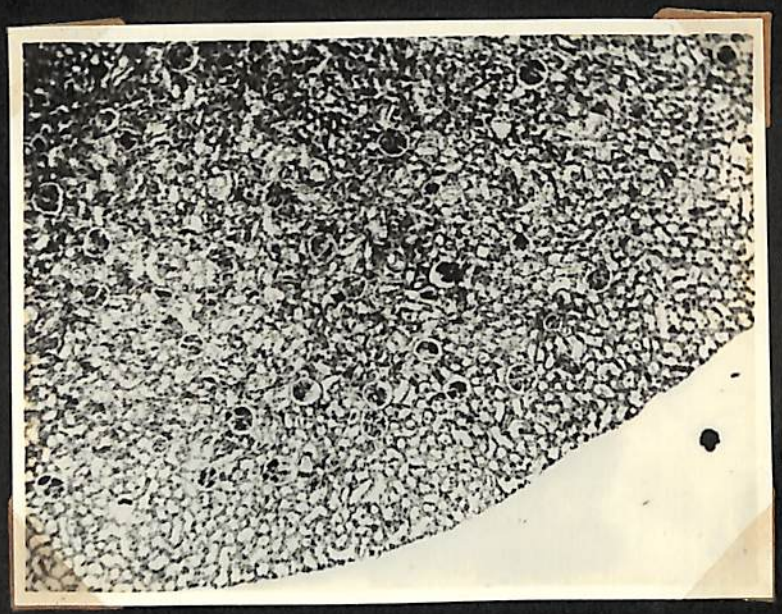


Plate 3.

KIDNEY. Note the normal histological structures Haematoxylin and Eosinx100.

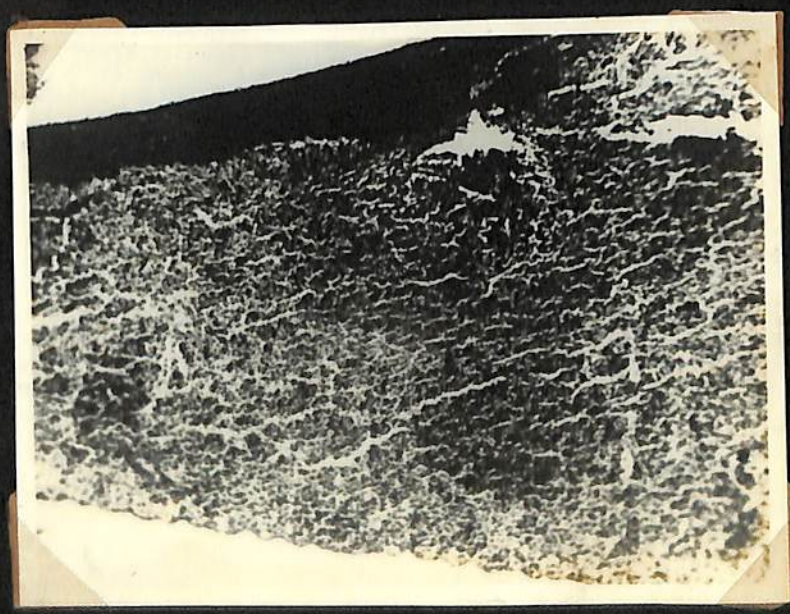


Plate 4.

SPLEEN. Note the normal histological structures Haematoxylin and Eosin x 100.